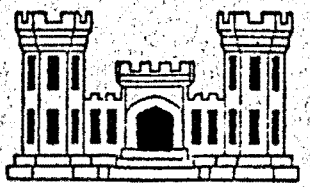
CROTON RIVER BASIN

LEVEL II

CARMEL DAM
(WEST BRANCH RESERVOIR)

PUTNAM COUNTY, NEW YORK
INVENTORY NO. 29

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM



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This report provides information and analysis on the physical condition of the dam as of the report date. Information and analysis are based on visual inspection of the dam by the performing organization.

Carmel Dam was judged to safe, no remedial measures were required.

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CROTON RIVER BASIN

LEVEL II

CARMEL DAM
(WEST BRANCH RESERVOIR)

PUTNAM COUNTY, NEW YORK
INVENTORY NO. 29

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

Prepared by: TIPPETTS-ABBETT-McCARTHY-STRATTON

NEW YORK DISTRICT CORPS OF ENGINEERS

MAY 24, 1978

CROTON RIVER BASIN
CARMEL MAIN AND AUXILIARY DAMS
INVENTORY NO. 29
PHASE I INSPECTION REPORT

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PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam:	CARMEL MAIN AND AUXILIARY DAMS (I.D. NO. 29)
State Located:	NEW YORK
County Located:	PUTNAM COUNTY
Stream:	WEST BRANCH, CROTON RIVER
Date of Inspection:	24 APRIL 1978

ASSESSMENT

The examination of available documents and visual inspection of Carmel Main and Auxiliary Dams and their appurtenant structures did not reveal conditions that are considered to be unsafe. Some deficiencies and inadequacies related to maintenance and operation were observed.

The total discharge capacity of the spillway and regulatory outlets at maximum pool level is approximately 37,000 cfs. This is less than the estimated probable maximum flood (PMF) of 59,000 cfs, but greater than the standard project flood (SPF) of 22,700 cfs, both as determined by the Corps of Engineers Screening criteria. The project discharge capacity is therefore adequate in accordance with the Corps of Engineers adopted general principle that structures be designed for the maximum flood reasonably characteristic of the region, which is, in practice, the Standard Project Flood.

No remedial measures are required at the present time.

The following improvements are recommended:
- Correct spillway seepage at Main Dam
- Observe and/or correct seepage at left abutment of Main Dam
- Remove vegetation from the embankments
- Clean the Auxiliary Dam drainage outlets
- Repair 36-in. gate valve at Auxiliary Dam
- Develop programs for operation and maintenance

Eugene O'Brien
New York No. 29823

Approved By: Col. Clark H. Benn
New York District Engineer

Date: 31 June 78

GENERAL VIEW OF CARMEL MAIN DAM, SPILLWAY AND GATEHOUSE

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
CARMEL MAIN AND AUXILIARY DAMS
INVENTORY NO. 29
CROTON RIVER BASIN
PUTNAM COUNTY, NEW YORK

SECTION I PROJECT INFORMATION

1.1 GENERAL

a. Authority

The Phase I Inspection reported herein was authorized by the DEPARTMENT OF THE ARMY, NEW YORK DISTRICT, CORPS OF ENGINEERS by letter dated 31 March 1978, in fulfillment of the requirements of the National Dam Inspection Act, Public Law 92-367, 8 August 1972.

b. Purpose of Inspection

The purpose of this inspection and report is to investigate and evaluate the existing conditions of subject dam in order to: identify deficiencies and hazardous conditions; determine if they constitute hazards to human life or property; and notify the State of New York of these results along with recommendations for remedial measures where necessary.

1.2 DESCRIPTION OF THE PROJECT

a. Description of the Main Dam

Carmel Main dam is composed of two earth embankment segments built on the sides of a masonry spillway. The upstream slope of the embankments is 1 (V): 2 (H) and the downstream slope is 1 (V): 2.36 (H). The width of the crest is 15 feet. The length of the embankment segment left of the spillway (looking downstream) is 1099.5 ft and on the right 435 ft. The maximum height of the embankment is 83 ft on the left and 86 ft on the right. Both embankments have a vertical masonry central core wall which extends through the entire length of the right embankment and a substantial distance into the left embankment. The width of the core wall is 55 ft at the base and 4 ft at the top; its maximum height is 77 ft. The downstream slope, crest and approximately a 10 ft wide top portion of the upstream slope are covered with grass; the remainder of the upstream slope is covered by hand placed cut stone slope protection.

The spillway is an ungated structure built of masonry rubble and faced with regular courses of cut stone which on the downstream slope are stepped. The width of the spillway is 260 ft and its crest at El 503. The

structural height between stream bed and crest is 55 ft.

The regulating outlet system is composed of a double, parallel arrangement located in the gate house which is to the left of the spillway. The outlets are controlled by four manually operated 24-in. x 60-in. sluice gates, two on the upstream side and two on the downstream side. The intakes to the regulating outlets are located at El 456, El 476 and El 496. The high level intakes are presently closed by stop logs. The outlet has two discharge openings at El 456.

b. Description of the Auxiliary Dam

The Auxiliary dam is an earthfill structure with the following dimensions: crest width: 25 ft, upstream slope, 1 (V): 2(H): downstream slope, 1 (V): 2.5 (H). The downstream slope is grass covered except for a portion near the toe which is covered by stone protection, indicating the possible presence of a toe drain which is probably associated with the foundation drainage system described below. The crest is paved since Route 6 passes over this embankment. The upstream slope, below a 10 ft wide grass covered strip near the crest, is protected by hand placed cut stones. The length of the embankment is 749 ft and its maximum height is 65 ft. There is a masonry rubble center core wall in this embankment; the wall is 12 ft wide at the base, 5 ft wide at the top, and has a maximum height of 66 ft. A foundation drainage system, composed of several branches collects the under-seepage and the water is directed to collector vaults where it is taken away in underground conduits. The collector vaults and conduits, which are outside of the embankment, are built of cut stones and form 18 inch square sections at most places. There is a larger brick-stone enclosure for a former spring located near the left abutment contact, which also serves as one of the collector points for the system.

There is no spillway at the Auxiliary dam.

The low level outlet is a 3 ft diameter masonry conduit leading from the upstream toe to a central gate house and shaft where a 24 in. x 60-in. manually operated sluice gate controls the flow. Inside the gate house the low level conduit at El 460 joins a high level intake located at El 496. At present, the upper intake is closed by stoplogs. Downstream of the gate house, the outlet consists of a 36-in. pipe inside a brick conduit which terminates in a valve vault located at the downstream toe. The downstream control for the low level releases is a 36-in. gate valve located in this vault.

Downstream of the vault, the 36-in. pipe continues underground and discharges into a circular fountain.

c. Location

Carmel Main Dam is located on the West Branch of the Croton River about 1.5 miles southwest of Carmel, New York. The auxiliary dam was built over a small tributary of the West Branch, and it is located about 1.2 miles southwest from the Main Dam. The portion of Route 6 between Carmel and Mahopac passes on the right abutment of the main dam and over the crest of the auxiliary embankment.

d. Size Classification

The main dam is 62 ft high and the auxiliary dam is 50 ft high. Both dams are therefore classified as "intermediate" size (between 40 and 100 feet).

e. Hazard Classification

The dams are in the "high" hazard potential category.

f. Ownership

The dams on the West Branch reservoir are owned and operated by the Bureau of Water Supply (BOWS) of the City of New York. The operation and maintenance is managed by the Carmel Section Office of the East-of-Hudson Division of BOWS.

g. Purpose of Dam

The dam provides storage for the New York City water supply system.

h. Design and Construction History

The main and auxiliary dams and their appurtenances were designed by the Aqueduct Commission of New York. The contract for the construction was let in 1890 to M.S. Coleman and the construction completed in 1895.

i. Normal Operating Procedures

Water is released through the regulating facilities of the two dams into the West Branch of the Croton River which carries the water to Croton Falls Main Reservoir. The approximate quantities released are 5 mgd at the main dam: and 2 mgd at the auxiliary dam. A much larger quantity however, approximately 180 mgd, is discharged from the reservoir into the New York City water supply system by releasing water into the Delaware Aqueduct at Shaft 10 which is located to the left and near the Auxiliary dam. Delaware Aqueduct, located near the upstream end of the reservoir, is capable of releasing water into the West Branch Reservoir; this inlet, however, is usually closed.

1.3 PERTINENT DATA

	Main Dam	Auxiliary Dam
a. Drainage Area - sq. mi.	42.87	
b. Discharge at Dam Site - cfs		
Maximum known flood at site (Oct. 16, 1955)	3,600	
Maximum regulatory outlets	700	175
Discharge at Shaft 10	285	
Ungated spillway at maximum pool (El 515)	36,000	-
Total discharge capacity, at maximum pool	37,000±	
c. Elevation: feet above MSL		
Top of embankment	515.0	515.0
Normal Operational Pool	502.0	502.0
Maximum design pool (top of slope protection)		
Spillway crest	503.0	503.0
Stream bed downstream of dam	450.0	450.0
d. Reservoir		
Length of maximum pool, miles	3.0	
Length of shoreline at spillway crest level, miles	15.6	
Surface area at spillway crest level, acres	1082.8	
e. Storage acre-feet		
Top of spillway crest, El.503	30,900	
Maximum design pool - top of slope protection El.510	38,200	
Maximum pool - top of dam, El.515	42,300	
f. Dams		
Type: Earthfill embankment with masonry Rubble Core Wall		
Length, ft.	1534.5	749
Upstream Slope	1(V): 2(H)	1(V): 2(H)
Downstream Slope	1(V): 2.5(H)	1(V): 2.36(H)
Width of Crest, ft.	15	25

	Main Dam	Auxiliary Dam
Impervious Core: Rubble Masonry		
Bottom Width, ft.	55	12
Top Width, ft.	4	5
Maximum Height, ft.	86	65

g. Spillway

Type: Ungated - stepped downstream face

Length, ft: 260 -

Upstream Channel: None

Downstream Channel: 435 ft long; 60 ft wide to Rt. 6.

h. Regulatory Outlets

At Main Dam: Intakes on three-levels controlled by two 24-in. x 60-in. sluice gates. Double outlet conduits controlled by two 24-in. x 60-in. sluice gates.

At Auxiliary Dam: Two-level inlet controlled by 24-in. x 60-in. sluice gate. 36-in. downstream discharge pipe controlled by 36-in. diameter gate valve.

At Shaft 10: Six 4 ft x 12 ft sluice gates discharging into Delaware Aqueduct.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

a. Geology and Foundation Conditions

There is no information on site geology or foundation conditions in the files of the Bureau of Water Supply. The report to the Aqueduct Commissioner (Reference 9) which contains the as-built drawings, also has a number of photographs taken during construction. These photographs give some indication of the foundation condition. The project drawings included in the report to the Aqueduct Commissioner indicate that the spillway and part of the central core wall adjacent to the spillway are resting on bedrock but the embankment and the rest of the core wall may be founded probably on surficial glacial deposits. There is no record of a foundation investigation program made prior to construction and there are no data on exploratory borings.

The geology of the region has been studied in detail in the past and data concerning the general geological conditions of the area can be found in the literature (References 8 and 9).

The site of West Branch Dam and Reservoir is underlain by a series of Precambrian formations, primarily granitic gneisses and paragneisses. These formations are considered to be excellent foundation materials for water retaining or other engineering structures. In most parts of the area, there is only a shallow surficial deposit over the rock. A minor fault is indicated in the area of the reservoir, it passes near the left abutment of the main dam. The fault, which is thought to be inactive, strikes in the NW-SE direction.

b. Embankments and Appurtenant Structures

The two dams and their appurtenant structures located on the West Branch Reservoir were designed in 1890 by the Aqueduct Commission of New York. The original contract drawings differ from the as-built conditions, in many respects. Another set of drawings is included in the Aqueduct Commission's report, 1887-1895 (Reference 9); these drawings more accurately reflect the as-built structures. In addition, a drawing was located at the BOWS offices which shows the layout of the foundation drainage system at the Auxiliary Dam. The list of drawings examined during this investigation is given in the Appendix. The general approach employed in the design of these dams is described in E. Wegmann's book (Reference 1).

2.2 CONSTRUCTION RECORDS

There is little information available on the construction; the Aqueduct

Commission Report 1887-1895 (Reference 9) contains data on the bidding process, the contract award and cost. It also contains a short description of the construction work which is illustrated in construction photographs (Plates 18-23, Reference 9).

2.3 OPERATION RECORD

BOWS records the pool elevations and rainfall daily and also keeps records of repair and maintenance work orders. No operation and maintenance manuals exist and there is no written record of inspections.

2.4 EVALUATION OF DATA

The data reviewed is considered adequate for this Phase I investigation. The data has been made available by the BOWS' New York City Office, the Katonah Office and the Carmel Section Office. Verbal descriptions of the procedures, and information on the operation and maintenance were also received from the District Engineer, Section Engineer and Foreman, who cooperated with the inspection team in all respects.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General

The visual inspection of Carmel Main and Auxiliary Dams was made on April 24, 1978. The weather was sunny to partially cloudy; the inspection was made 5 days after the last rainfall. The reservoir level at the time of inspection was 1 ft below spillway crest, El.502.

b. Main Embankment and Abutments

The embankment is generally well maintained; there are no visible signs of major slides, sloughing, erosion, cracks or other distress. There are no signs of unusual conditions on the abutments which would adversely effect the functioning of the dam. The following minor irregularities or deficiencies are noted: (The locations of these observations corresponding to the capital letters in parenthesis are marked on the sketches in the Appendix).

(A) Trees are growing near and at the upstream toe of the left embankment.

(B) Seepage emerges from the lower portion of the abutment contact of the left embankment. The water appears near the old paved collector ditch and flows in and near the ditch. The surface of the embankment and abutment in the area of seepage is wet and soggy. The embankment surface shows minor irregularities which are thought to be made by the maintenance tractor in the wet ground. Because of the soggy surface the vegetation was not cut in the area.

(C) Wet, soggy ground exists but no seepage water appears at the lower part of the abutment contact of the right embankment. Surface irregularities similar to those found at the left abutment were also noted here.

(D) Some bushes are growing on the downstream slope of the right embankment near the spillway wall.

(E) There are some animal burrows (approximately 8-in. in diameter) on the left abutment near the embankment contact.

(F) Minor damage has been noted in the stone slope protection at the far right end of the right embankment.

(G) The upstream stone slope protection has developed a depression and a bulge to the right of the spillway. In this area there is a crack in the slope protection which is associated with the slight downward movement of the stones.

c. Auxiliary Embankment and Abutments

The auxiliary embankment is well maintained and it is in good condition. There are no signs of problems or adverse conditions on the two abutments. This embankment has a foundation drainage system which is apparently still functioning. The following minor irregularities and deficiencies are noted:

(H) The access vaults and manholes of the drain system are partially clogged with debris, sand and leaves. The seepage measuring weirs of the system are not operational.

(I) There is minor erosion made by surface runoff from the highway on the downstream slope near the left abutment contact.

(J) The stone protection on the upstream slope has developed some minor damage on both sides of the gate house.

(K) Some saplings and bushes are growing on the upstream slope.

d. Spillway

The spillway structure appears to be sound and in acceptable operating condition. There are no significant cracks or signs of major deformations or movements. Some of the facing stones are slightly weathered but in satisfactory condition. The top two rows of facing stones were replaced in the early 1950's.

The following deficiencies are noted:

(L) Although the inspection was made at a time when the reservoir level was below spillway crest, considerable amounts of water were cascading on the downstream face of the spillway. The water emerged from between the joints of stones facing the spillway at all levels but the heaviest flow came from the joints of the top 2 or 3 layers.

(M) The top two layers of surface stones have been dislocated from their original position and pushed (probably by ice) downstream. The alignment of these two rows of stones has a downstream curvature.

e. Regulating Outlets

The operating gates of the main and auxiliary dams appear to be in working order, except:

(N) The 36-in. gate valve at the auxiliary dam is broken and stuck in a partially open position.

The brick conduit that surrounds the 36-in. outlet pipe inside the downstream portion of the embankment is in good condition and shows no signs of structural damage or distress.

There is no regular inspection schedule and maintenance program in effect.

The outlet facilities at Shaft 10 were constructed in 1949, much later than those at the two embankments. The facilities at Shaft 10 are regularly inspected, maintained and repaired.

f. Downstream Channel

At the main dam the downstream channel appears to be in good condition with no signs of erosion or slope failure.

(O) The stream bed and its banks downstream of the auxiliary dam are cluttered with debris and are overgrown with vegetation.

g. Reservoir

There are no noticeable sloughing, landslides or other signs of instability in the reservoir area adjacent to the dam.

3.2 EVALUATION OF OBSERVATIONS

The Phase I inspection did not reveal any condition which would significantly affect the safety of the dam or would require either immediate investigation or remedial measures. The irregularities and deficiencies described above require regular observations, some improvement and maintenance work.

The seepage through the spillway structure appears to enter the structure through the joints of the two top rows of dislocated surface stones. The water either surfaces downstream of these two rows of stones or continues downward behind the facing stones and exits through the joints at lower levels. While this condition does not appear to represent imminent danger, if left unattended, may lead to further damage to the structure, particularly when subjected to freezing and thawing cycles.

The quality of the upstream slope protection is excellent and its condition is good. There are minor damages located on the slope near structures, such as gate houses, and spillway walls. The presence of these structures probably contributes to the disturbing effect of the waves.

The remedial measures for improving the conditions are given in Paragraph 7.2.

SECTION 4 - OPERATIONAL AND MAINTENANCE PROCEDURES

4.1 PROCEDURES

The Carmel Reservoir discharges approximately 180 mgd into the Delaware Aqueduct of the New York City water supply system through Shaft No. 10, which is located near the auxiliary embankment.

Smaller discharges of 5 mgd and 2 mgd respectively, are released through the regulating outlets of the Main and Auxiliary Dams into the Croton Falls Main Reservoir, which also is a component of the New York City Water Supply System.

The water level is normally kept 1 or 2 feet below spillway crest (El 503). In summer months the reservoir level may drop as much as 15 feet below spillway crest.

4.2 MAINTENANCE OF DAM

There is no formally established program of inspection by BOWS personnel and there is no operation and maintenance manual for the project. The reservoir is visited frequently by the personnel of the Carmel Section Office but they do not necessarily examine the dam or other project features.

The grass surfaces of the main and auxiliary dams are mowed periodically but no regular maintenance procedures are in effect for the masonry structures and spillway. A system of drains and drain outlets located at the downstream slope of the auxiliary dam were found to be partially clogged with leaves and transported sand. Because these drains control the foundation seepage, it is mandatory that they be inspected and cleaned regularly. The seepage discharge should be monitored and recorded on a systematic basis.

4.3 MAINTENANCE OF OPERATING FACILITIES

The regulating gates appeared to be in operational condition. The 36-in. diameter gate valve on the auxiliary dam discharge line, however, is not in working order. The valve stem is damaged and the valve is jammed in a partially open position. The regulating gates are opened and closed about every six months to check their functioning.

4.4 WARNING SYSTEMS IN EFFECT

There are no warning systems in effect or in preparation.

4.5 EVALUATION

The maintenance of the Carmel Dam is considered adequate except in the following areas:

a. Disrepair of the 36-inch gate valve at the auxiliary dam.

b. Seepage at the top two rows of stones at the spillway sill.

c. Maintenance of the drainage system at the auxiliary dam is less than adequate.

d. There is some vegetation on the surfaces of the embankments.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 DRAINAGE AREA CHARACTERISTICS

The drainage area contributing to the West Branch Reservoir is 42.87 square miles and consists of steep hills, interspersed with swamp and natural lakes typical of a glaciated region. These lakes and swamps are believed to provide a substantial storage, capable of modifying the peak flood runoffs.

5.2 SPILLWAY CAPACITY

The spillway is uncontrolled, with a flat crest 260 feet long and approximately 3.0 feet wide, followed by a stepped downstream face. A spillway discharge rating, up to a head of 1.5 feet was obtained from the Department of Water Supply, but it was necessary to extend this table to a head of 12.0 feet corresponding to the top of the dam. It was assumed that the spillway would act as a broad-crested weir up to a depth of 5.0 feet, and as a "sharp-crested" weir above this depth. The computed spillway capacity at a head of 12.0 feet is 36,000 cfs (839.5 cfs per sq. mi.).

5.3 RESERVOIR CAPACITY

The total reservoir capacity at the spillway crest is 10,070 million gals (30,900 acre-feet). The storage capacity curve, based on a table furnished by the Department of Water Supply is shown on Figure 2. The capacity curve has been extrapolated to an elevation corresponding to the top of the dam (Elevation 515.0), and indicates a surcharge storage of 11,400 acre-feet, which is equivalent to a runoff depth of 5.00 inches over the drainage basin. This surcharge storage is an important factor in considering the adequacy of the spillway's capacity to pass the design floods.

a. Floods of Record

Historic data of known floods in the Croton River Basin indicates that the largest floods were those of August and October, 1955. Daily readings of the head on the spillway crest gave the following data on these floods:

Date	Elevation in feet	Head in feet	Discharge cfs	Discharge cfs/sq. mi.
August 21, 1955	504.85	1.85	1800	42
October 16, 1955	505.83	2.83	3600	84

The records of precipitation at the dams indicates that, in the August storm, 6.83 inches of rain fell from the eleventh to the thirteenth inclusive, followed by 7.17 inches on the 17th and 18th, a total of 14 inches in eight days. The October storm was 9.9 inches, occuring in three days, 14-16 inclusive, and was of greater intensity, 6.77 inches falling on October 15. However, the spillway discharge was relatively low due to the storage available in the reservoir prior to the storms, on August 11th and October 14 when the water surface was 8.78 feet and 1.98 feet below spillway crest, respectively.

b. Overflow Potential

The maximum spillway discharge of 36,000 cfs, given in Paragraph 5.2 above, has been compared with the generalized design flood criteria as explained below. The Probable Maximum Flood for the 42.87 square mile drainage area has been extrapolated from Maps of Probable Maximum Flood Potential for selected sizes of drainage area (Reference 11). The smallest drainage area for which floods have been plotted was 100 square miles. The extrapolation to 42.87 square miles must be considered approximate, but indicates a PMF peak inflow of about 59,000 cfs or about 1.6 times the spillway discharge capacity.

A second criteria for evaluating a design flood is the Standard Project Flood (SPF) which is usually about one half of the PMF. Derivations of the SPF in the Lower Hudson River Basin are available in a report made for the Corps of Engineers (Reference 12). Data in this report permitted interpolation of the SPF for an area of 42.87 square miles and indicated a flood potential of 22,700 cfs or 63% of the spillway capacity.

5.5 EVALUATION

The estimated Probable Maximum Flood inflow of 59,000 cfs, and the Standard Project Flood inflow of 22,700 cfs must be considered as representing potential inflow to a reservoir from a drainage area that has little natural or artificial storage. The Carmel Main Dam drainage area has substantial natural storage, and to properly evaluate the relation between its spillway capacity and the probable outflow from these design floods, it would be necessary to develop complete hydrographs and route them through the substantial surcharge storage. A greater refinement would require development of sub-area hydrographs which would be routed through the natural storage in each sub-area. Without these detailed analyses, it is not possible to say whether or not the spillway capacity is adequate relative to the runoff from a Probable Maximum Flood, but the capacity is obviously adequate to pass the Standard Project Flood.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations

Visual observations did not indicate significant problems or major deficiencies which would represent an imminent danger to the project.

The seepage noted at left abutment contact of the main dam is not detrimental to project safety unless it increases in quantity or the water turns muddy.

The pronounced curvature of the top masonry courses near the middle of the spillway is assumed to be caused by ice pressure. During the winter of 1977-78 there was as much as 26 inches of ice in the reservoir. The curvature might have been greater if steel rods had not been installed to anchor these top courses. The movement of the top masonry courses probably crushed any mortar in the joints resulting in some leakage through the joints. This is not considered a hazardous condition.

b. Design and Construction Data

No design computations or other data regarding the structural stability of the spillway or earth embankment are available.

On the basis of the performance experience of the spillway and earth embankment, as well as engineering judgement, these structures are not considered to be unstable.

Although there are no design computations available, it is likely that the spillway was designed in accordance with E. Wegmann's Text "Design and Construction of Dams". Mr. Wegmann, at the time the dam was put in service, was an Engineer for Construction, assigned the duty of making the theoretical studies and calculations for the Aqueduct Commission. It is assumed the spillway was designed accordingly and that its stability is sufficient. It should be noted that flashboards had been previously installed on top of the spillway without adverse effects.

Some photographs taken during construction for both the main and auxiliary dams are included in the Report to the Aqueduct Commissioner, 1887-1895 (Reference 9).

c. Operating Records

Records of gate operation and repairs are available in the BOWS' Section Engineer's office at the dam site. No major operational problems which

would affect the stability of the dam were reported.

d. Post Construction Changes

Prior to 1950 water was regularly discharged over the spillway but after the Aqueduct system was enlarged there was no regular release over the spillway.

The top courses of stone were probably in poor condition when they were replaced about 1951.

Before the floods of 1955, flashboards were regularly used on the spillways of the Croton System. The flashboards have since been removed and are no longer used. Holes are clearly visible on the top courses where the flashboards had been installed.

e. Seismic Stability

The dam is located in Seismic Zone No. 1 (Reference 13) therefore no seismic analyses are warranted.

SECTION 7 - ASSESSMENT/RECOMMENDED MEASURES

7.1 ASSESSMENT

a. Safety

The Phase I investigation of the Carmel Main and Auxiliary Dams on the West Branch Reservoir did not reveal any unsafe conditions. The irregularities and deficiencies described in Paragraph 3.1 do not constitute hazard to human life and property. Recommendations are given, however, in Paragraph 7.2 for improving the conditions related to these irregularities and deficiencies.

The total discharge capacity of the spillway and regulating gates without overtopping of the dam is approximately 36,000 cfs. This is less than the estimated probable maximum flood (PMF) of 59,000 cfs but greater than the standard project flood of 22,700 cfs, both as determined using the Corps of Engineer's screening criteria. The project discharge capacity is therefore adequate in accordance with the Corps of Engineers adopted general principle that structures be designed for the maximum flood reasonably characteristic of the region, which is, in practice, the standard project flood.

b. Adequacy of Information

The information available is adequate for performing this investigation. In addition to the existing information and data, however, the following items would be required for the proper operation and maintenance of the project:

(1) Up-to-date drawings of the Auxiliary Dam,
(2) Operation and maintenance manuals,
(3) Ratings for release facilities,
(4) Systematic schedule of inspection and record of inspection,
(5) Monitoring of seepage and record of the measurements, and
(6) Schedule and record of maintenance.

c. Urgency

No immediate action is required.

d. Additional Investigations

Additional investigations to assess the safety of the dams and appurtenant structures do not appear to be warranted at the present time.

7.2 RECOMMENDED MEASURES

No remedial measures are required at the present time.

Certain measures are recommended, however, for improving the conditions at locations noted in Paragraph 3.1.

a. The stonework, serving as spillway facing needs to be repaired in order to correct the seepage condition noted at locations (L) and (M).

b. The seepage and wet conditions noted at locations (B) and (C) should be systematically observed and possibly corrected by trench drains or protected by filter blankets.

c. The drain system of the Auxiliary Dam should be cleaned and new seepage measuring devices installed (Location (H)).

d. The 36-in. gate valve at Auxiliary Dam should be repaired (Location (N)).

e. The following measures can be carried out as part of the maintenance work: Removing trees and bushes, repairing minor damage and erosion of slope protection, clearing debris, and treating animal burrows. (Locations (A), (D), (E), (G), (I) and (K)).

f. Some of the observations, such as the minor upstream slope protection damages at locations (F) and (J) do not require any action at present, however periodic observations are recommended to detect potential further deterioration in the future.

g. For monitoring the performance of the embankment it would be desirable to reactivate the existing piezometers.

DRAWINGS

APPENDIX A

APPENDIX A

List of Drawings Reviewed in Connection
with Phase I Investigation of Carmel Main and Auxiliary Dams

DRAWINGS

From Report to the New York Aqueduct Commission 1887-1895 (As-Built Conditions) -

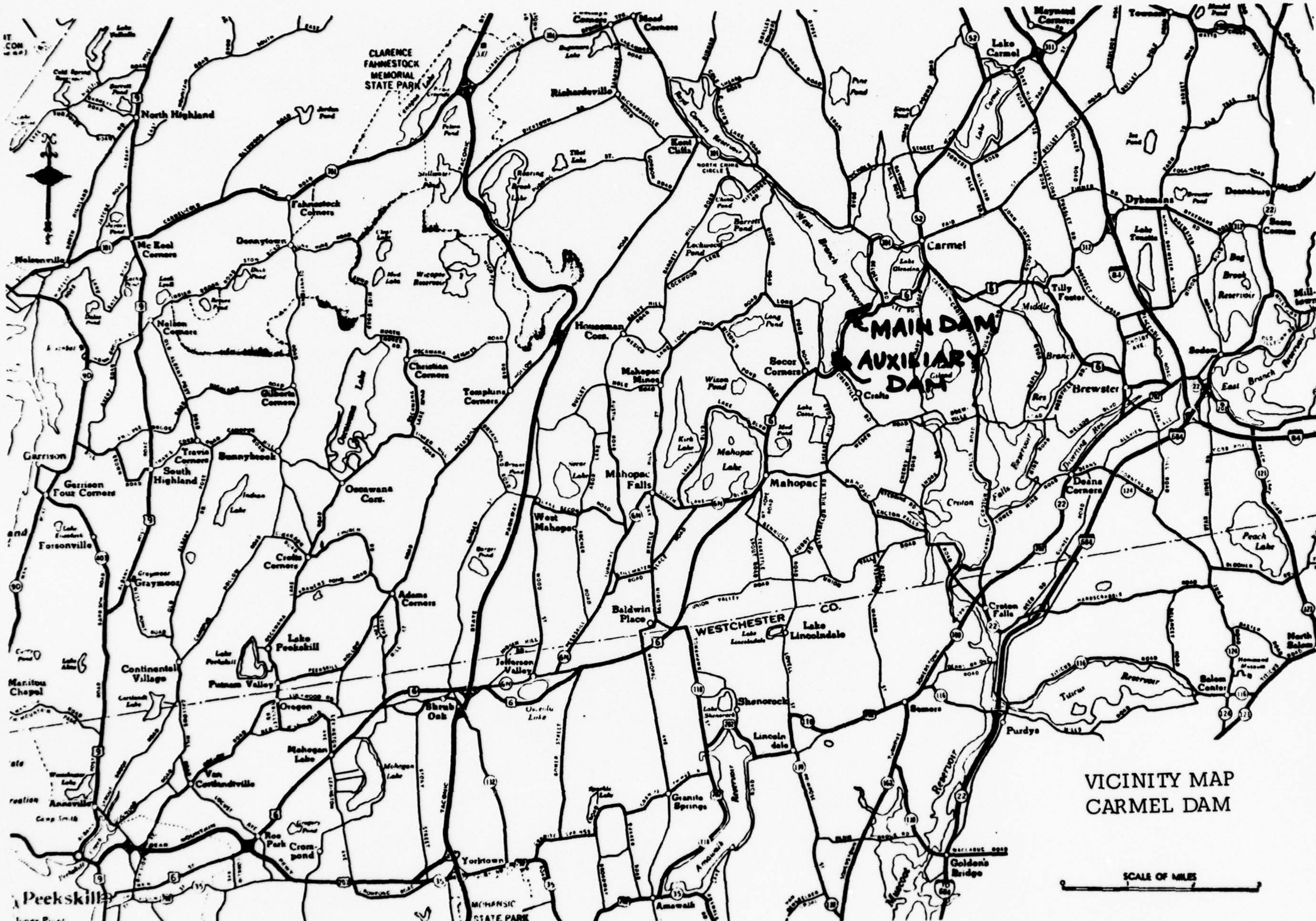
Sheet 18 - Contour Plan of Main Dam *
19 - Elevation and Section of Main Dam *
20 - Elevations and Sections of Auxiliary Dam *

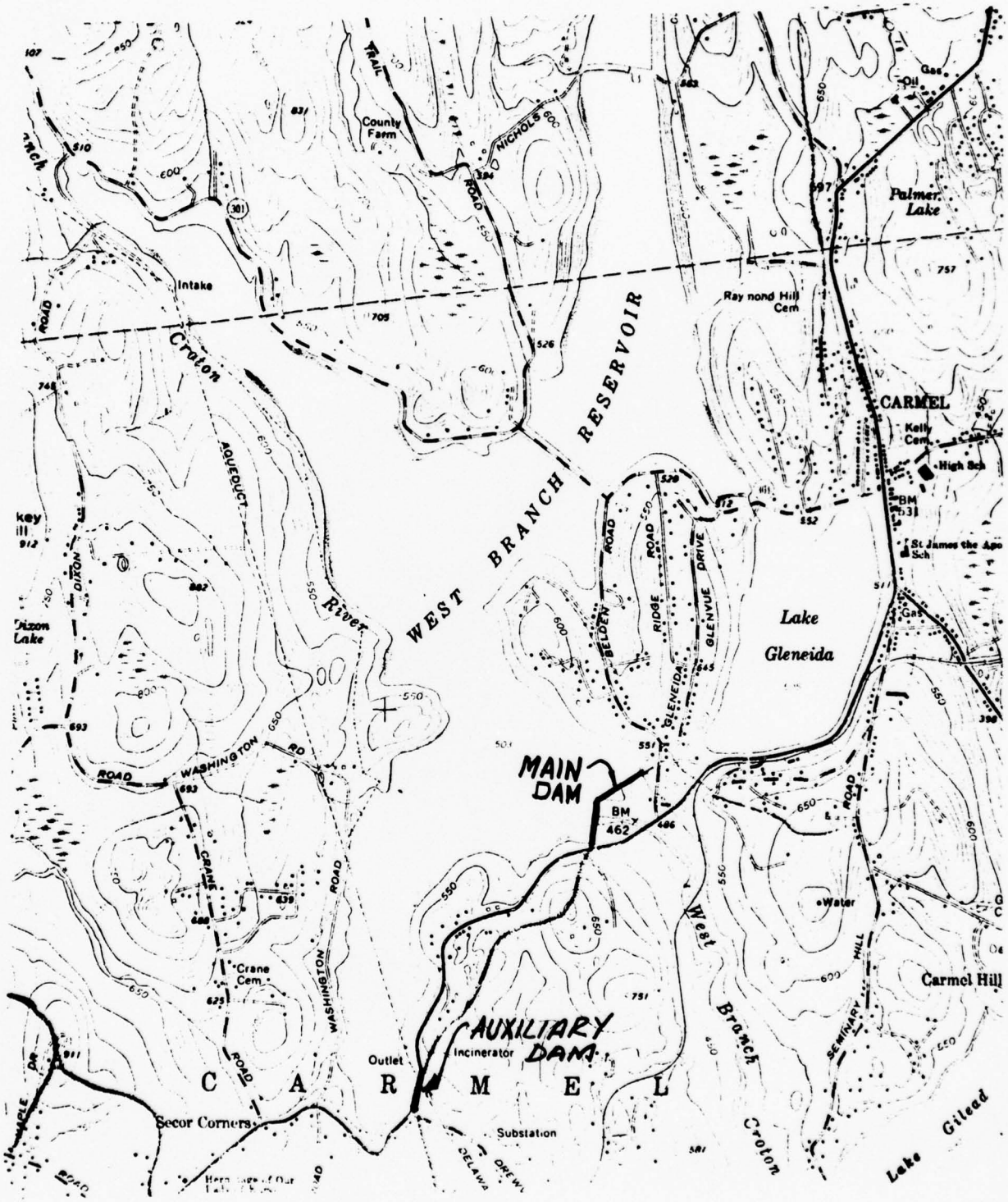
Plan and Sections of Auxiliary Dam Drainage System - Sections of Auxiliary Dam (BOWS Reference No. 3916-X) *

Contract Drawings: (Different from as-built conditions) (1890)

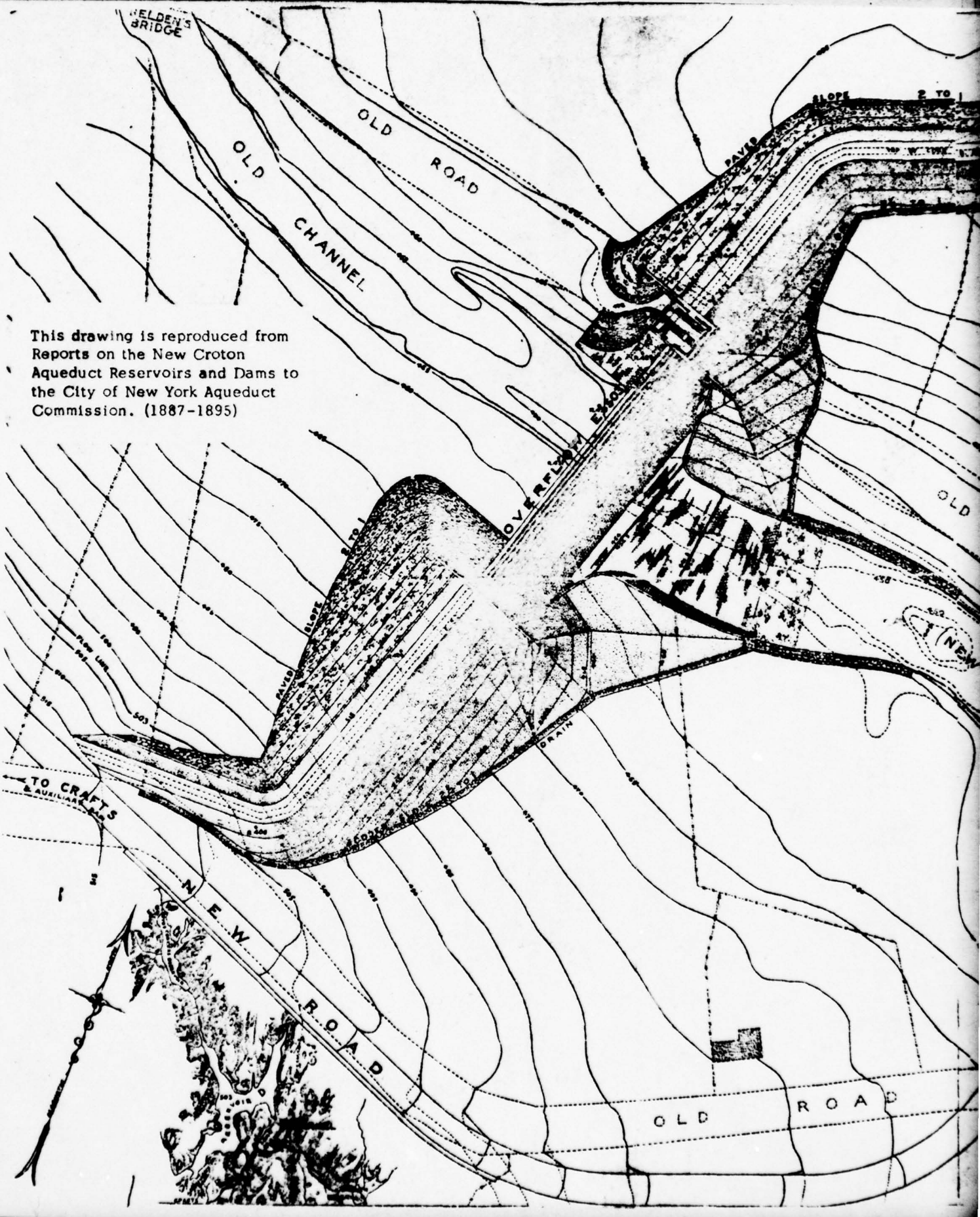
Sheet 2 - Plan of Auxiliary Dam
3 - Plan of Main Dam and Spillway
4 - Plan of Spillway
6 - Sections of Main Dam
9 - Section of Auxiliary Dam

*Drawings reproduced in this report - see Item b in this Appendix

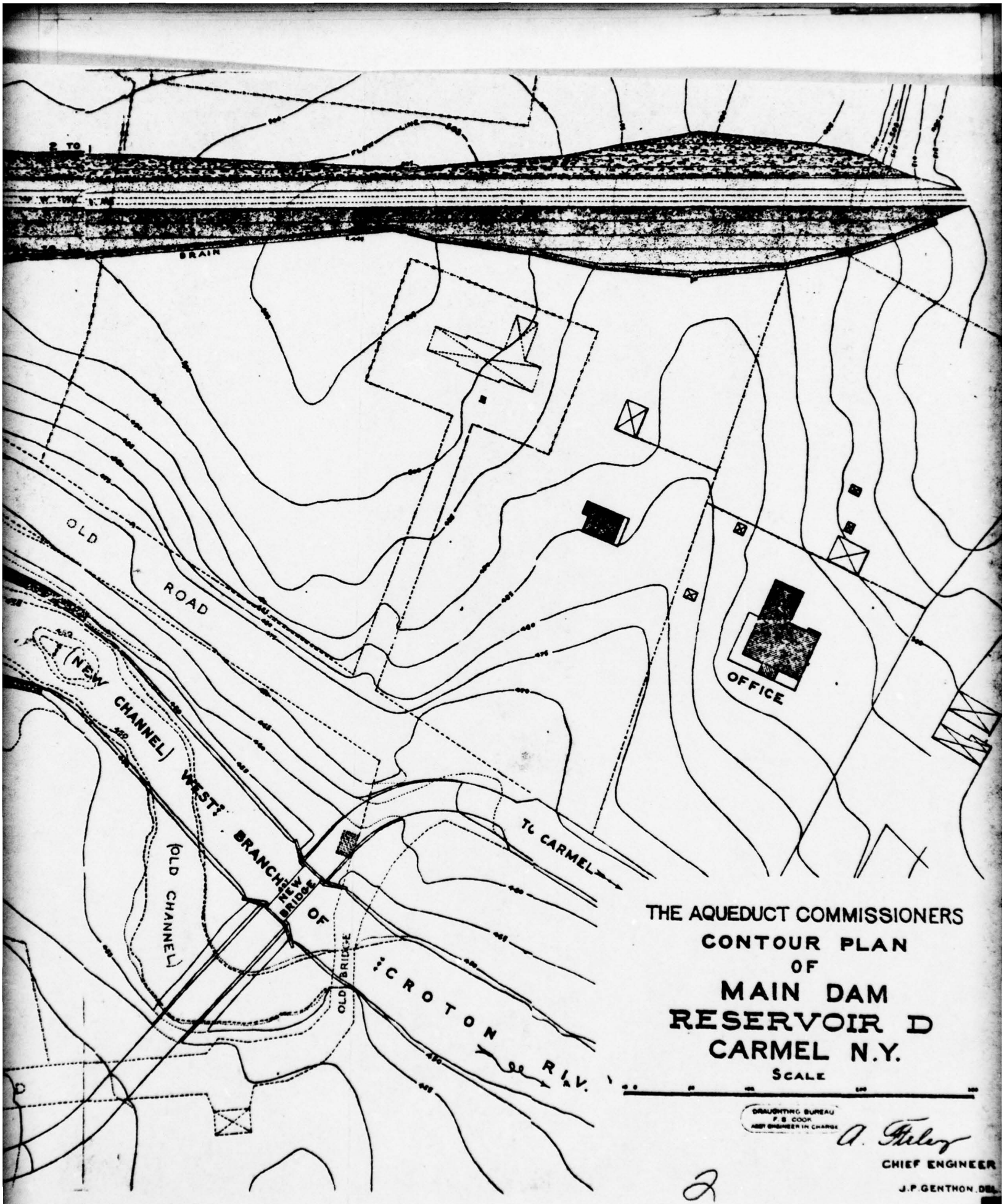

MAIN DAM
AUXILIARY DAM
CLARENCE FAHNESTOCK MEMORIAL STATE PARK
North Highland
Nelsonville
McKeel Corners
Dennytown
Fahnestock Corners
Richardsville
Kent Cliffs
Mead Corners
Lake Carmel
Carmel
Tilly Foster
Brewster
Dykemans
Deansburg
Sodom
Secor Corners
Mahopac
Mahopac Falls
Mahopac Lake
Crafts
Croton Falls
Doans Corners
Peach Lake
Houseman Corn.
Tompkins Corners
Christian Corners
Gilbert Corners
Nelson Corners
Travis Corners
South Highland
Garrison
Garrison Four Corners
Forsonville
Graymoor
Continental Village
Manitou Chapel
Crofts Corners
Oscawana Corn.
Adams Corners
Lake Peekskill
Putnam Valley
Oregon
Mohegan Lake
Van Cortlandtville
Peekskill
Jones Point
Annsville
Roa Park
Crompond
Yorktown
MOHANSIC STATE PARK
Shrub Oak
Jefferson Valley
West Mahopac
Baldwin Place
WESTCHESTER CO.
Lake Lincolndale
Shenorock
Lincolndale
Granite Springs
Amawalk
Somers
Purdys
Golden's Bridge
Salem Center
North Salem
Titicus Reservoir
West Branch Reservoir
East Branch Reservoir
Muscoot Reservoir
Amawalk Reservoir
SCALE OF MILES
VICINITY MAP
CARMEL DAM



TOPOGRAPHIC MAP
CARMEL DAM & RESERVOIR



This drawing is reproduced from Reports on the New Croton Aqueduct Reservoirs and Dams to the City of New York Aqueduct Commission. (1887-1895)



THE AQUEDUCT COMMISSIONERS

CONTOUR PLAN OF MAIN DAM RESERVOIR D CARMEL N.Y.

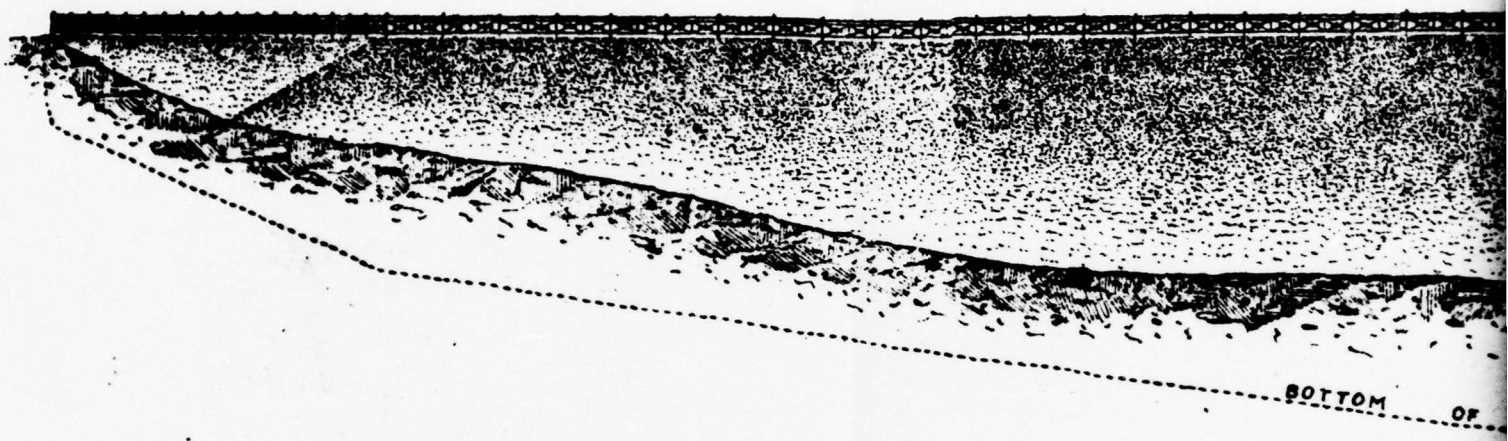
SCALE

DRAUGHTING BUREAU
F. S. COOK
ASST. ENGINEER IN CHARGE

A. Fteley
CHIEF ENGINEER

J.P. GENTHON, DEL.

2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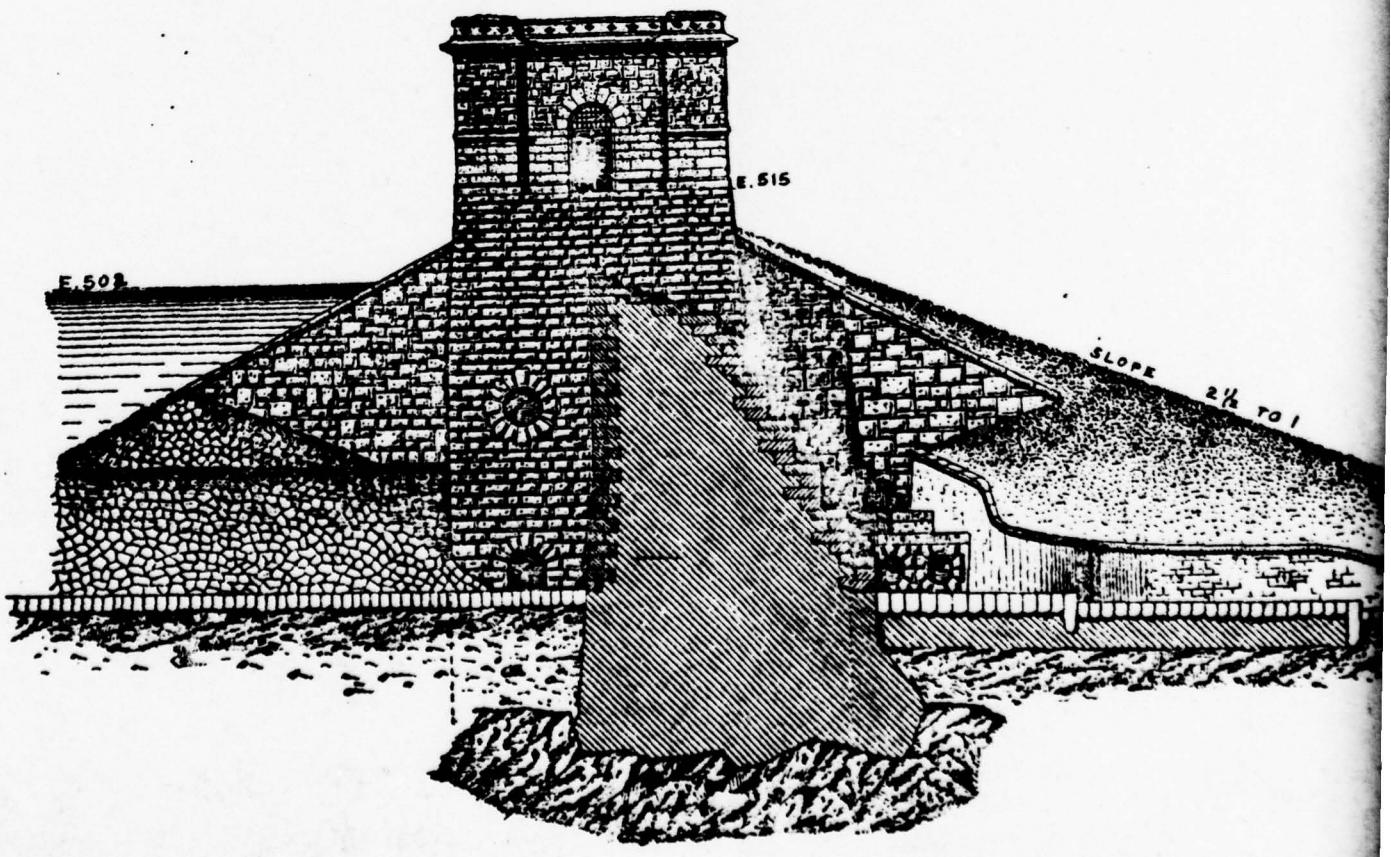
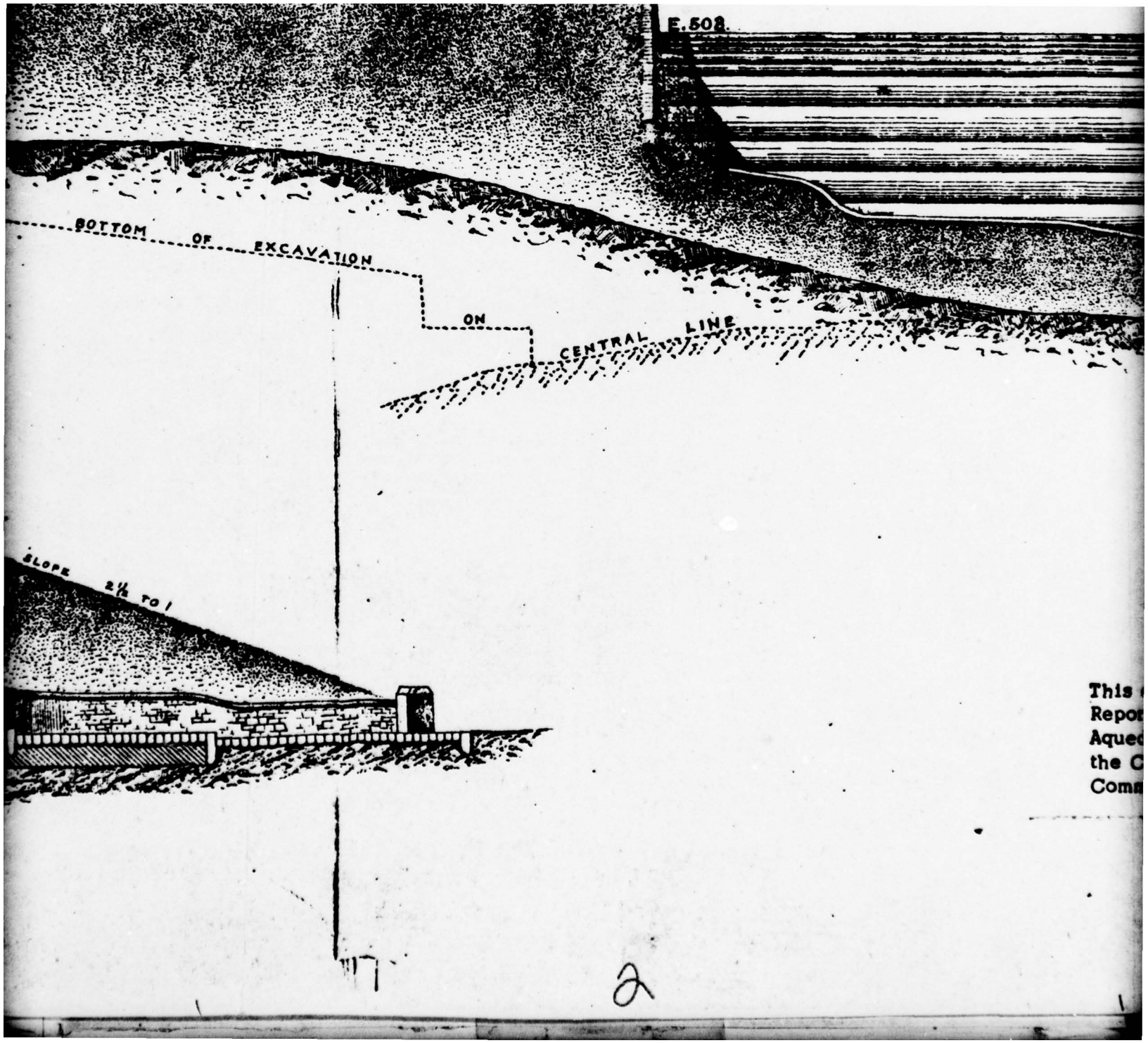

E. 515
E. 503
SLOPE 2½ TO 1



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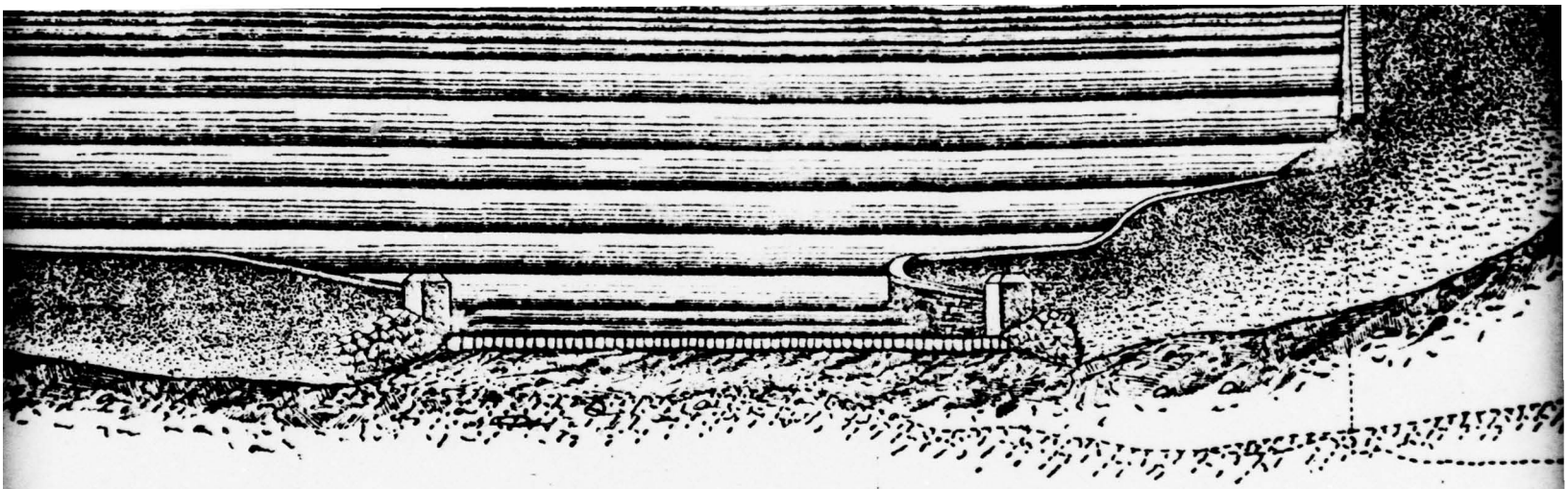

THE AQUEDUCT

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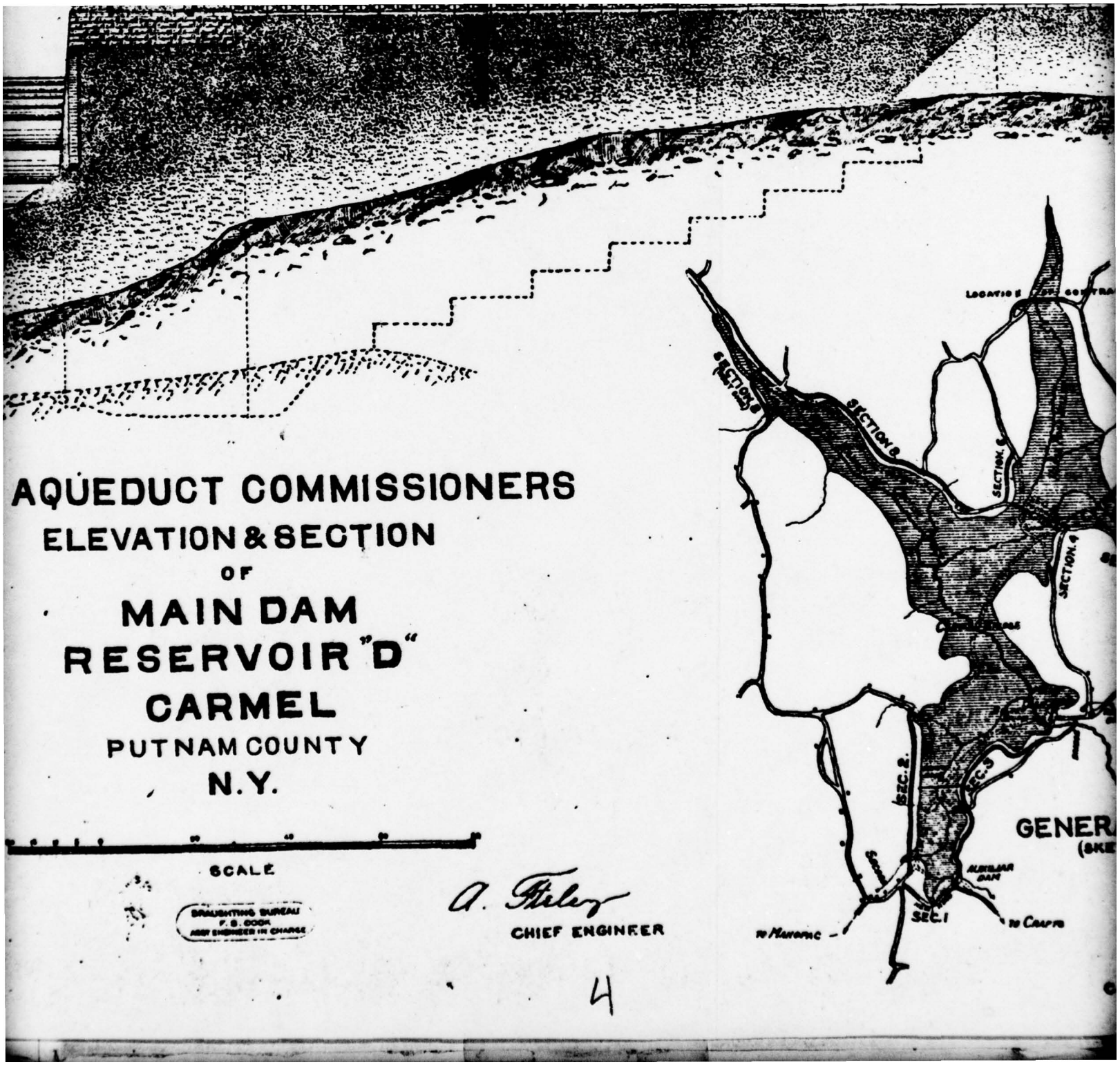


AQUEDUCT COMMISSIONERS

ELEVATION & SECTION

OF

MAIN DAM
RESERVOIR "D"
CARMEL

PUTNAM COUNTY

N.Y.

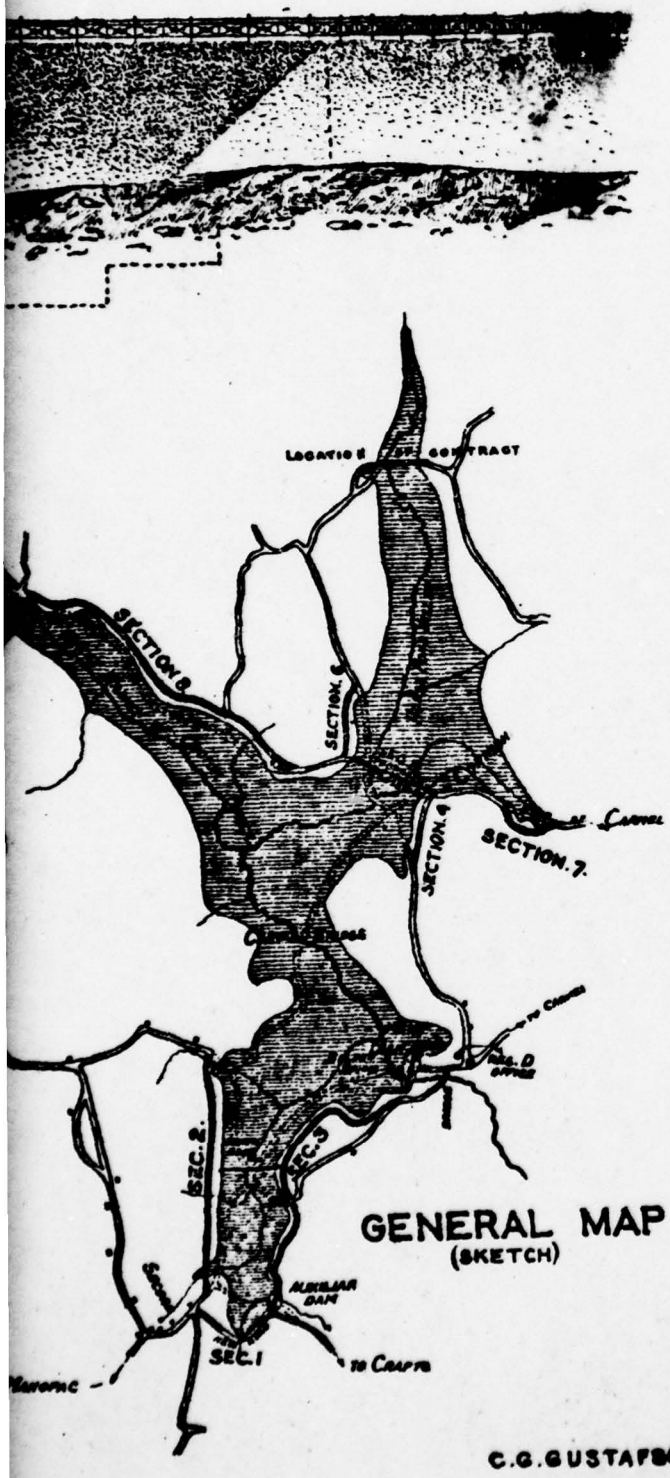
SCALE

DRAUGHTING BUREAU
F. S. COOK
ASST ENGINEER IN CHARGE

A. Fteley

CHIEF ENGINEER

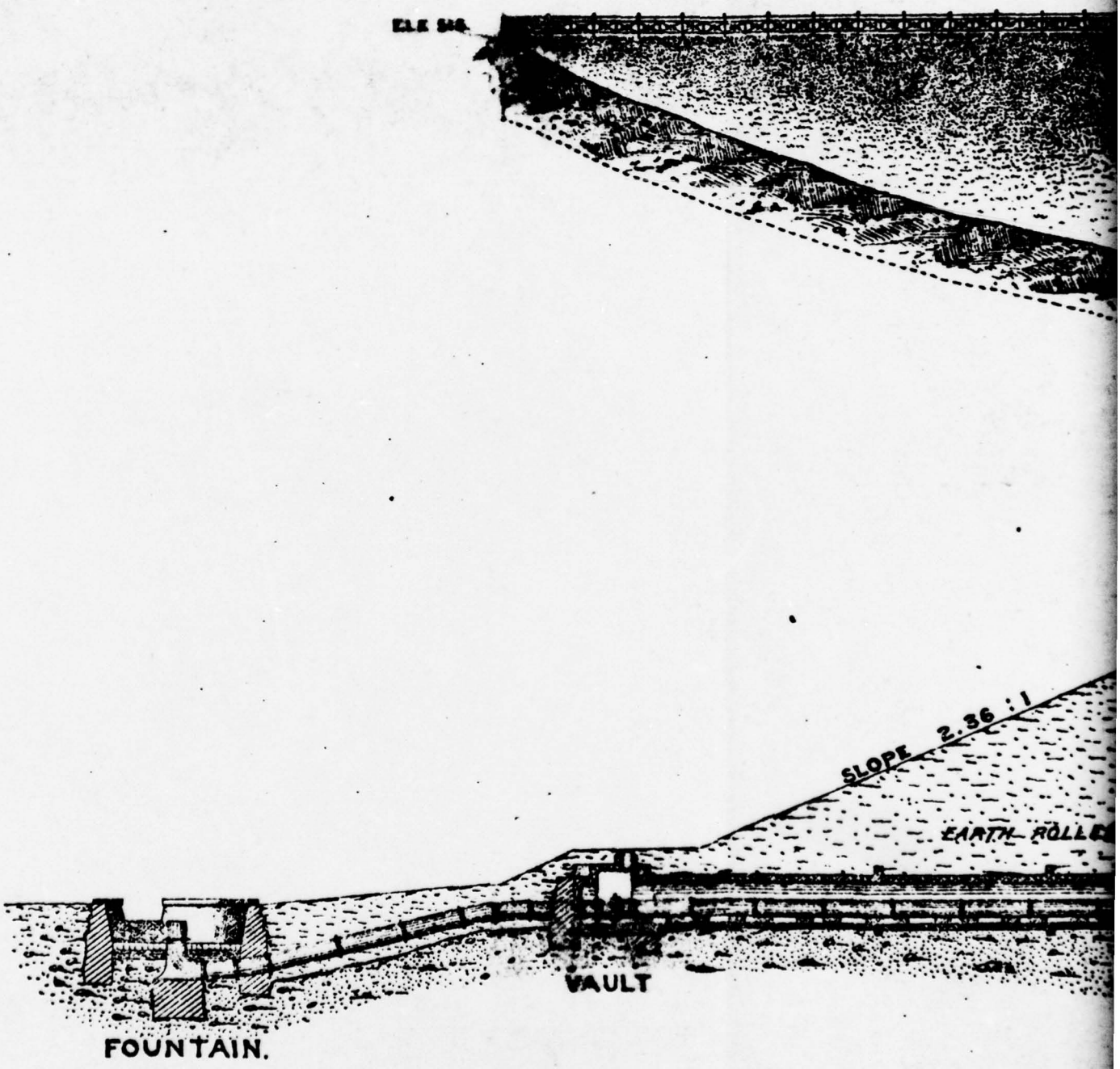
4



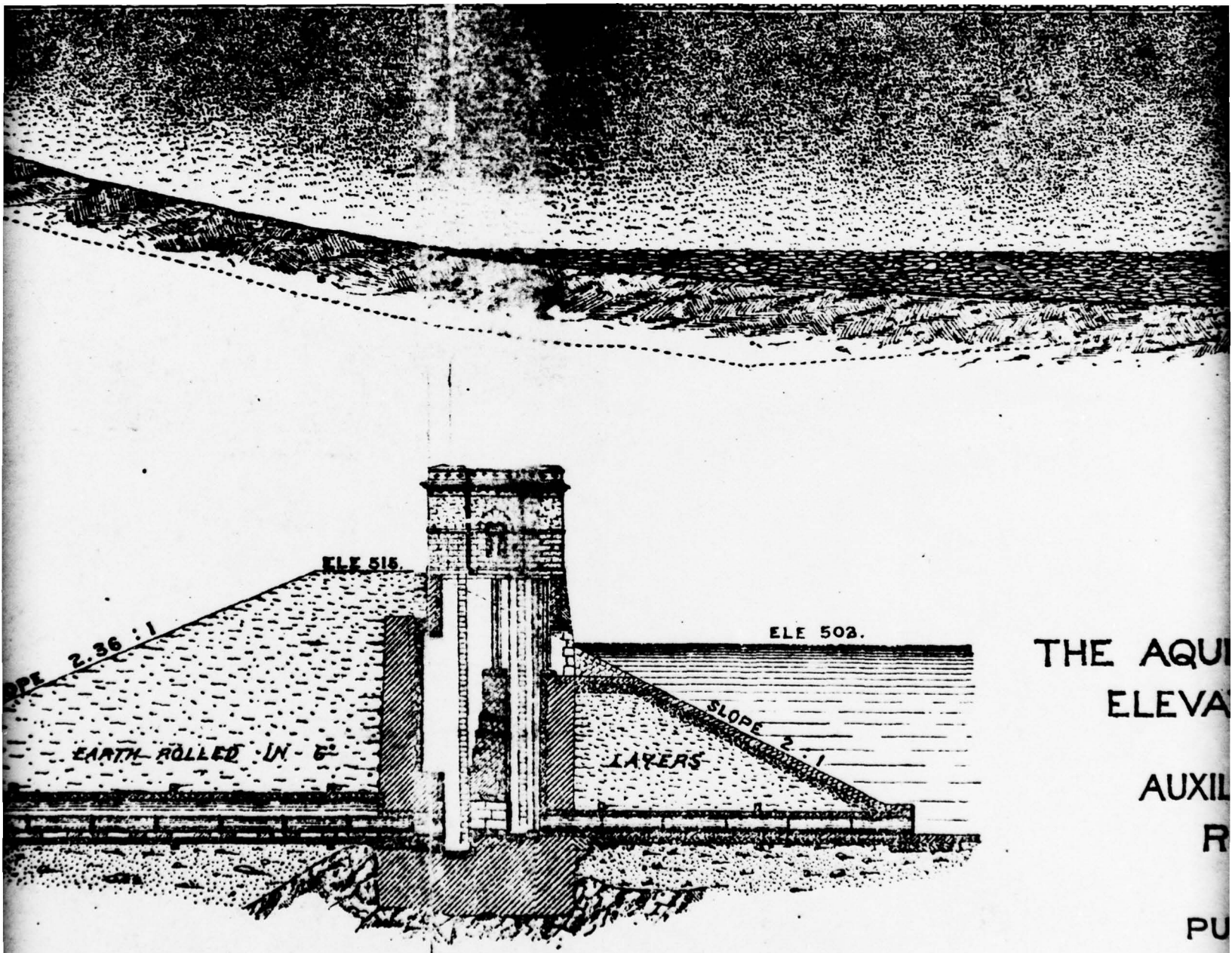
GENERAL MAP
(SKETCH)

C.G. GUSTAFSON, DEL.

5



SECTION



SECTION THROUGH GATE HOUSE.

THE AQU
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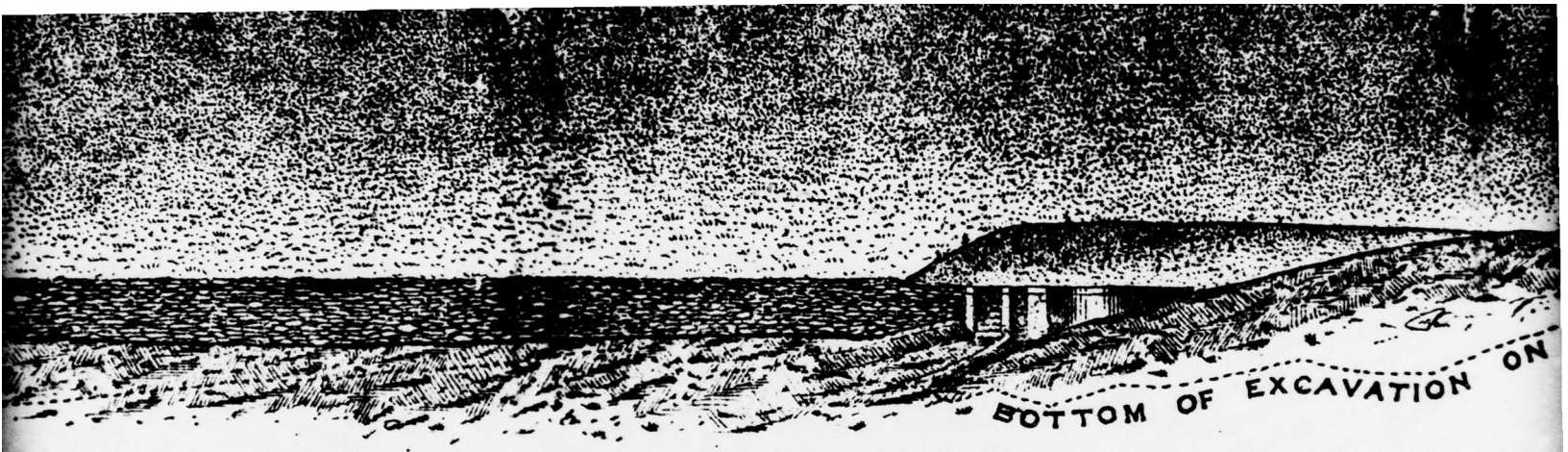


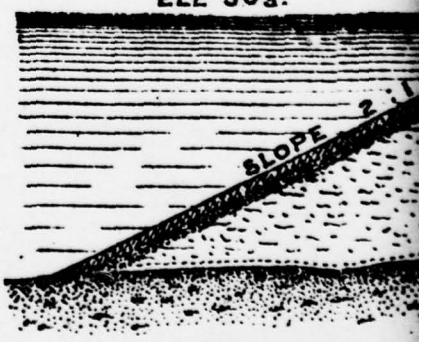
ELEVATION.

THE AQUEDUCT COMMISSIONERS
ELEVATION AND SECTIONS
OF
AUXILIARY EARTH DAM
RESERVOIR "D"
CARMEL
PUTNAM COUNTY N.Y.

SCALE

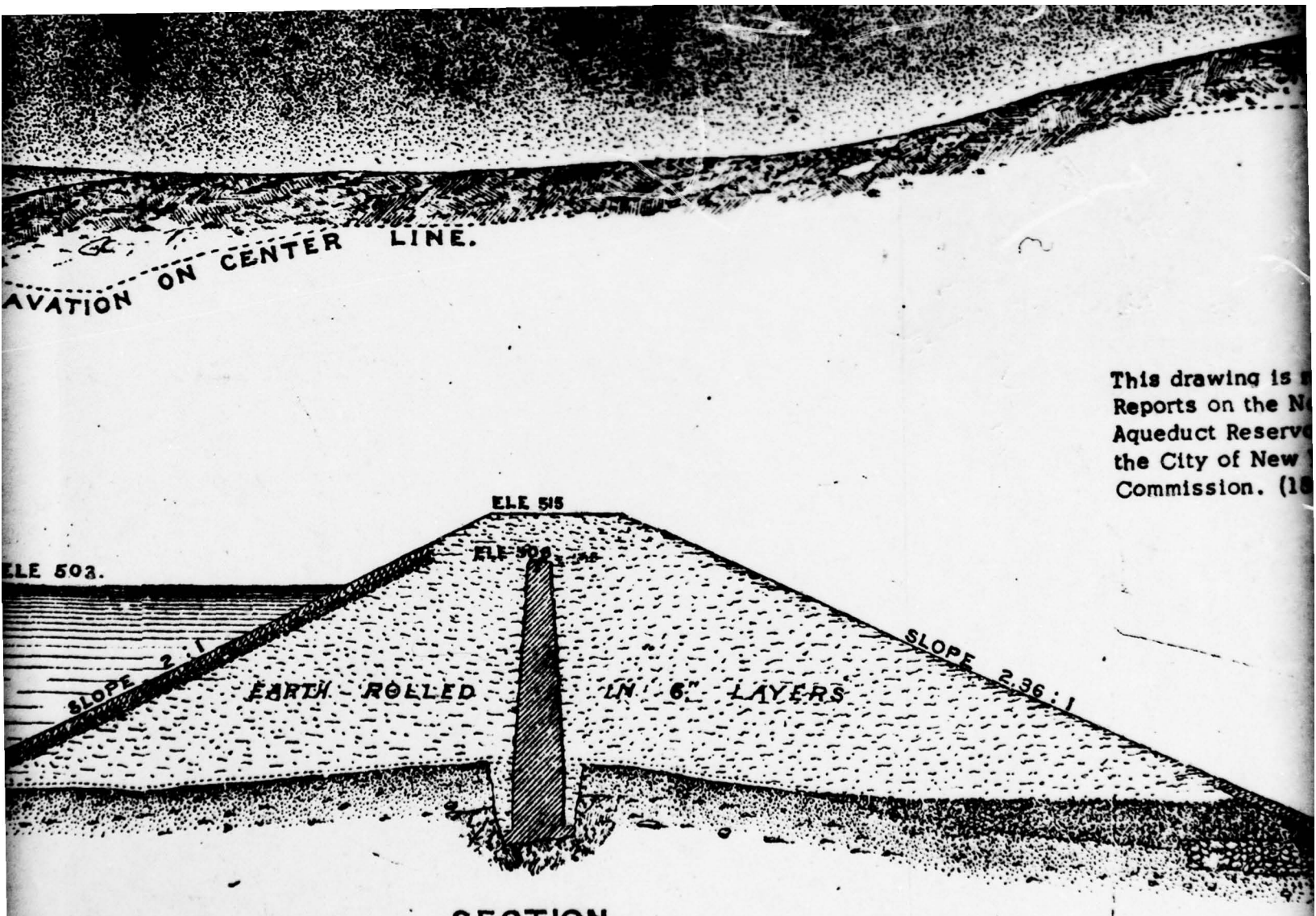
20' 15' 10' 5' 0' 20' 40'

DRAUGHTING BUREAU
F. S. COOK
ASST ENGINEER IN CHARGE



A. Fteley

3



SECTION.

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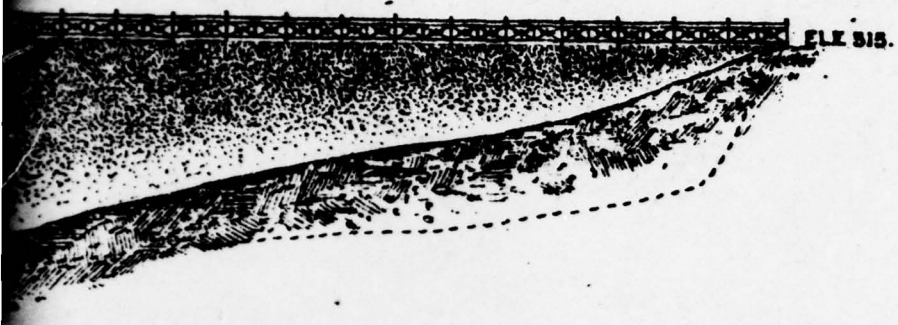
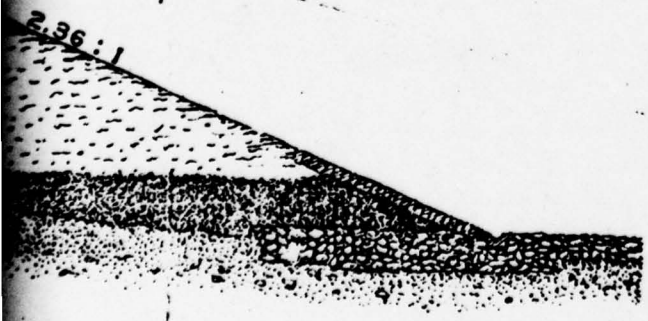
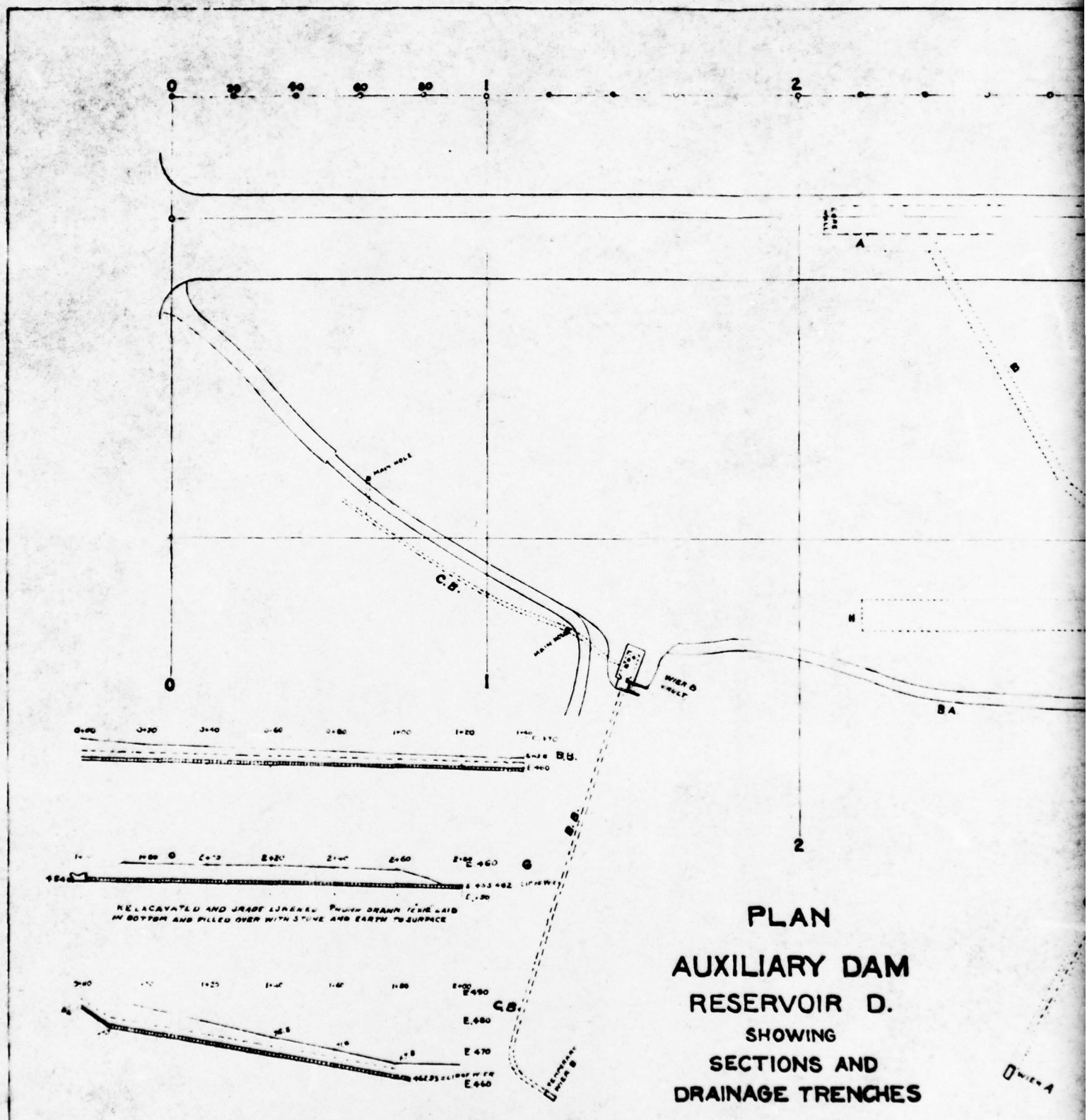
Reports on the N
Aqueduct Reserv
the City of New
Commission. (1



This drawing is reproduced from Reports on the New Croton Aqueduct Reservoirs and Dams to the City of New York Aqueduct Commission. (1887-1895)



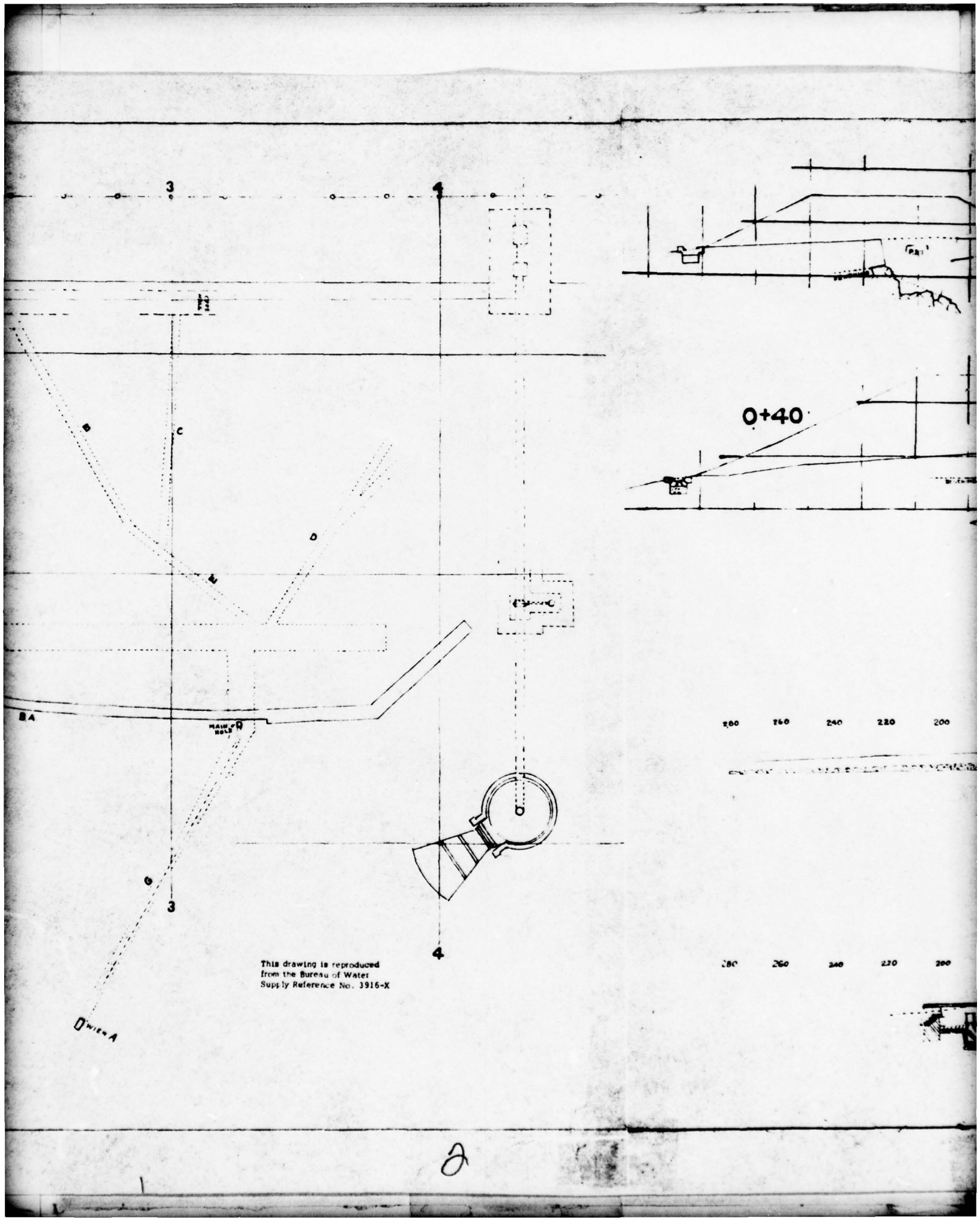


PLAN

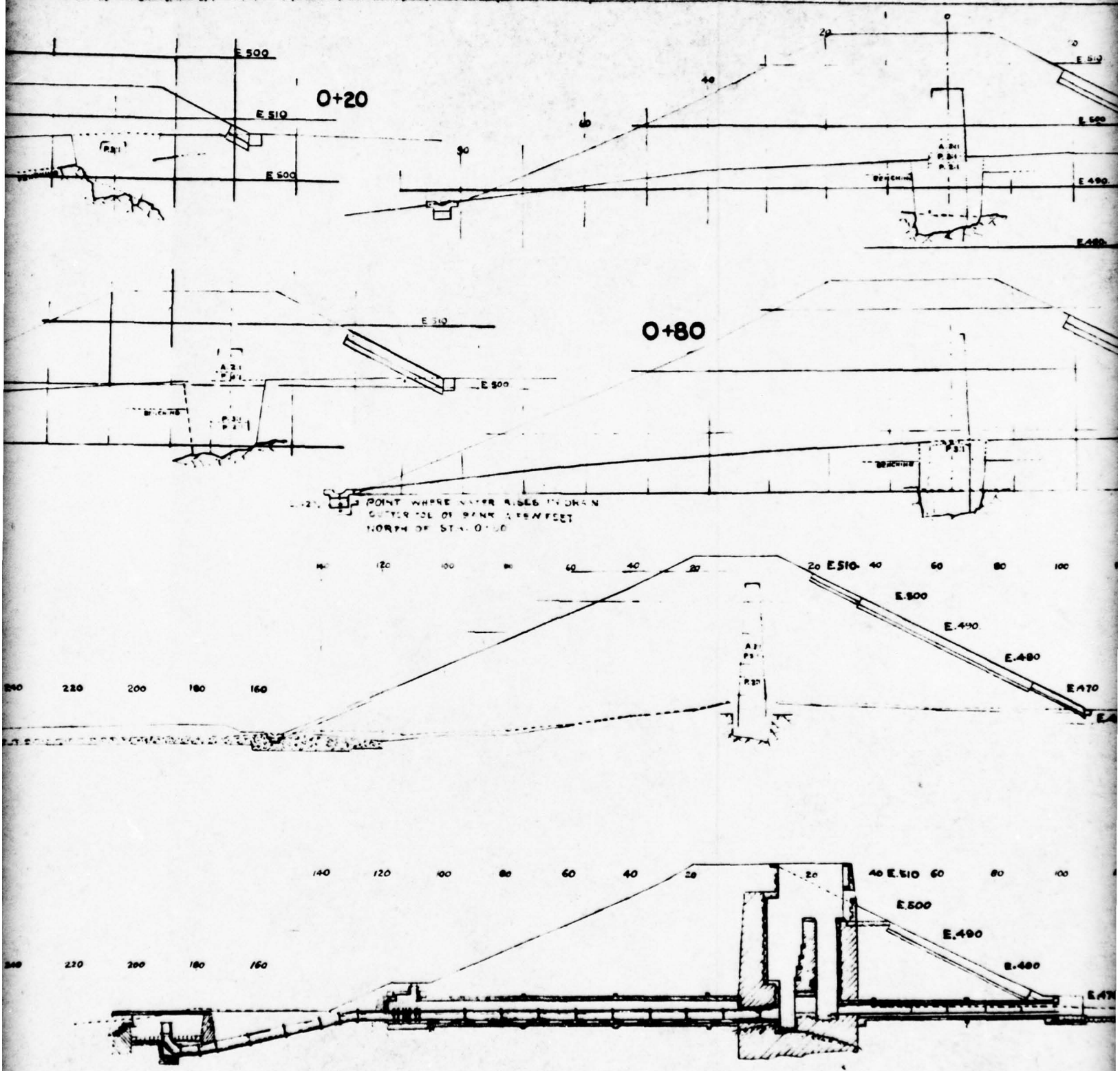
AUXILIARY DAM

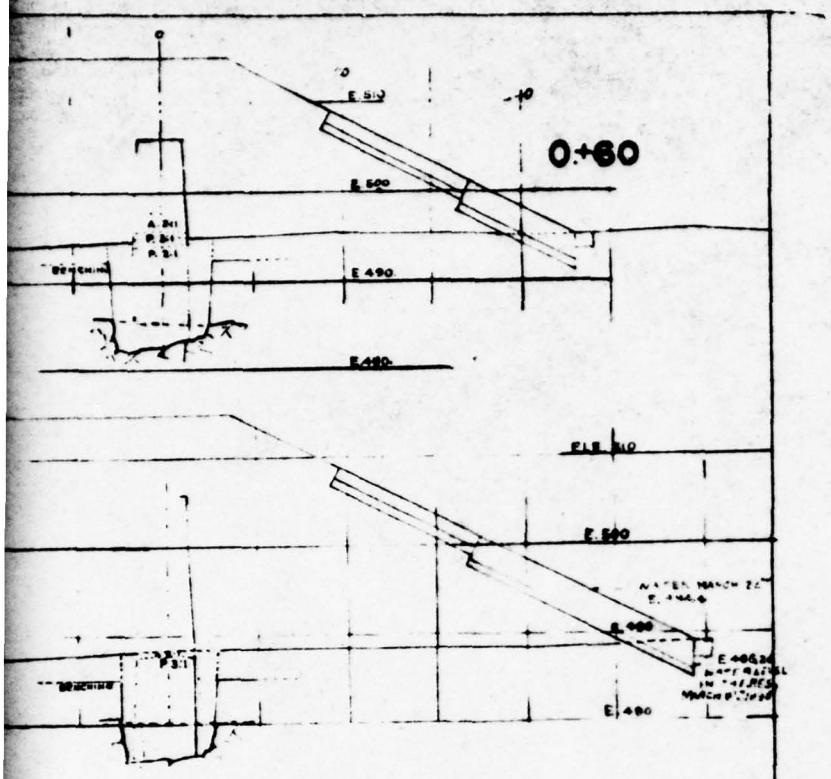
RESERVOIR D.

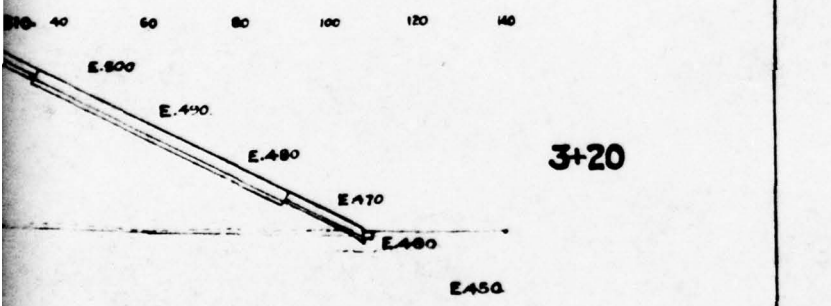
SHOWING SECTIONS AND DRAINAGE TRENCHES

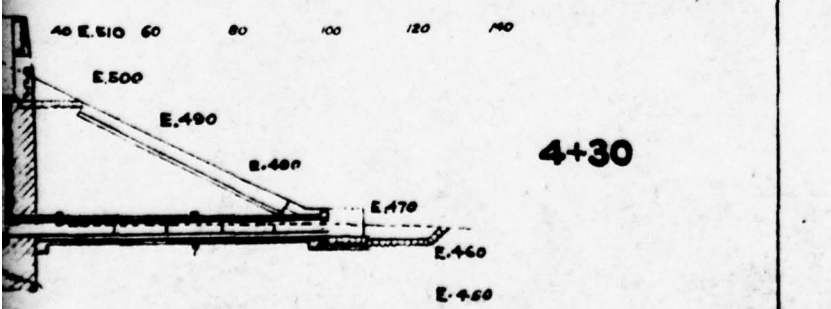


This drawing is reproduced from the Bureau of Water Supply Reference No. 3916-X


0+20
E 500
E 510
E 500
E 490
0+80
E 510
E 500
POINT WHERE WATER RISES TO DRAIN
GUTTER ON BANK 4 FEET
NORTH OF STA. 0+80
E.510
E.500
E.490
E.480
E.470
140
120
100
80
60
40
20
240
220
200
180
160







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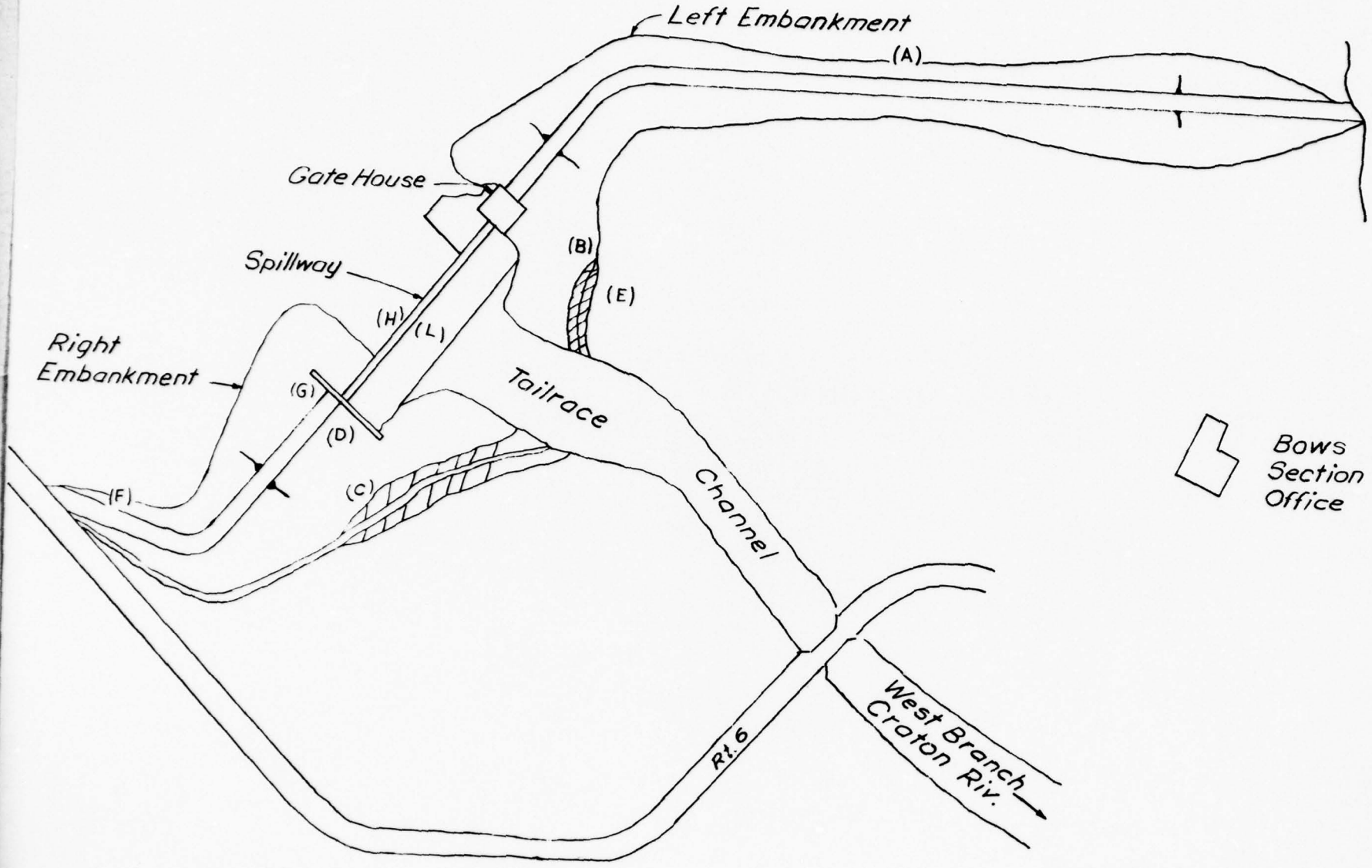
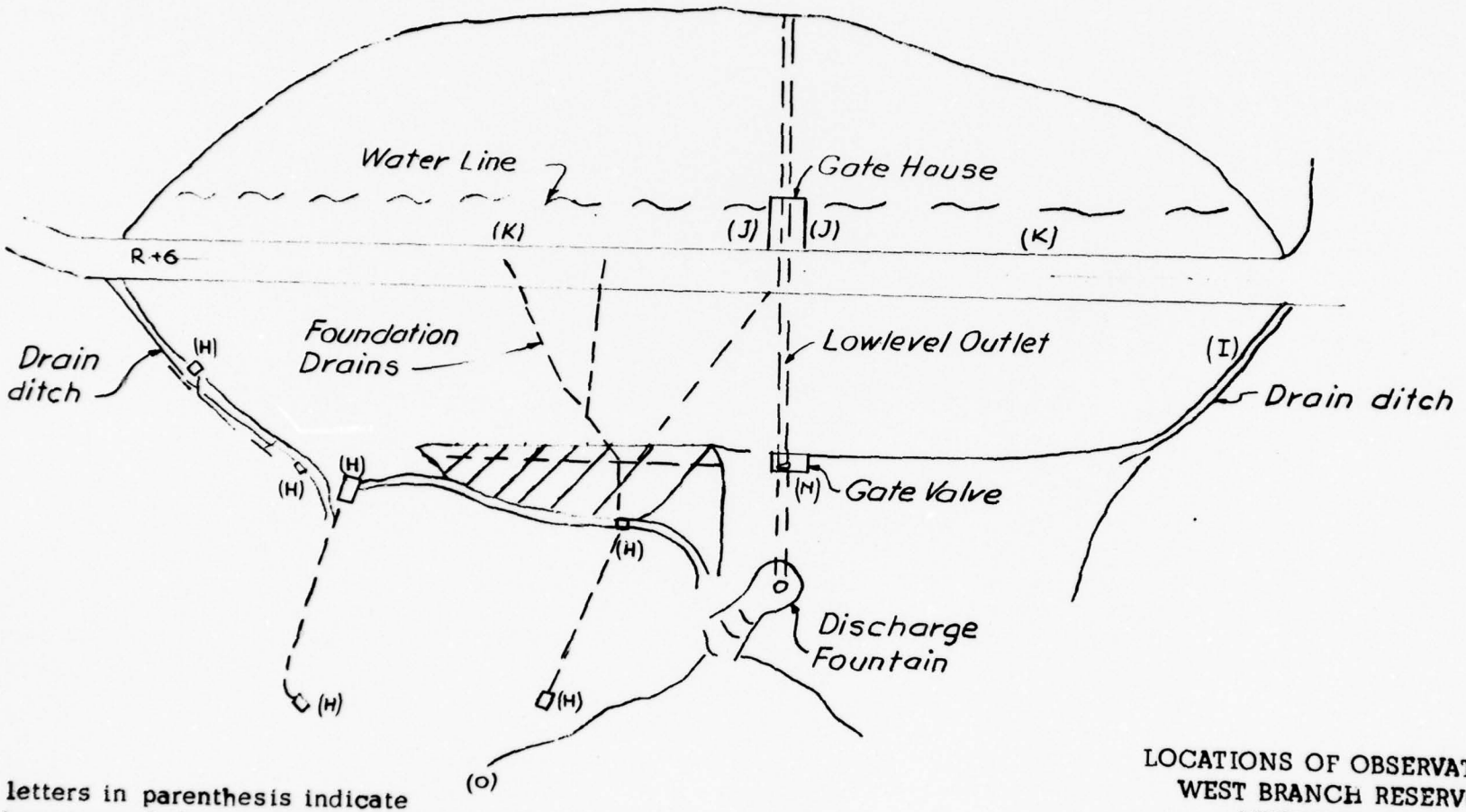


The letters in parenthesis indicate the locations of observations listed in Chapter 3.1.

LOCATIONS OF OBSERVATIONS
WEST BRANCH RESERVOIR
MAIN CARMEL DAM
NOT TO SCALE



The letters in parenthesis indicate the locations of observations listed in Chapter 3.1.

LOCATIONS OF OBSERVATIONS
WEST BRANCH RESERVOIR
AUXILIARY DAM
NOT TO SCALE

PHOTOGRAPHS

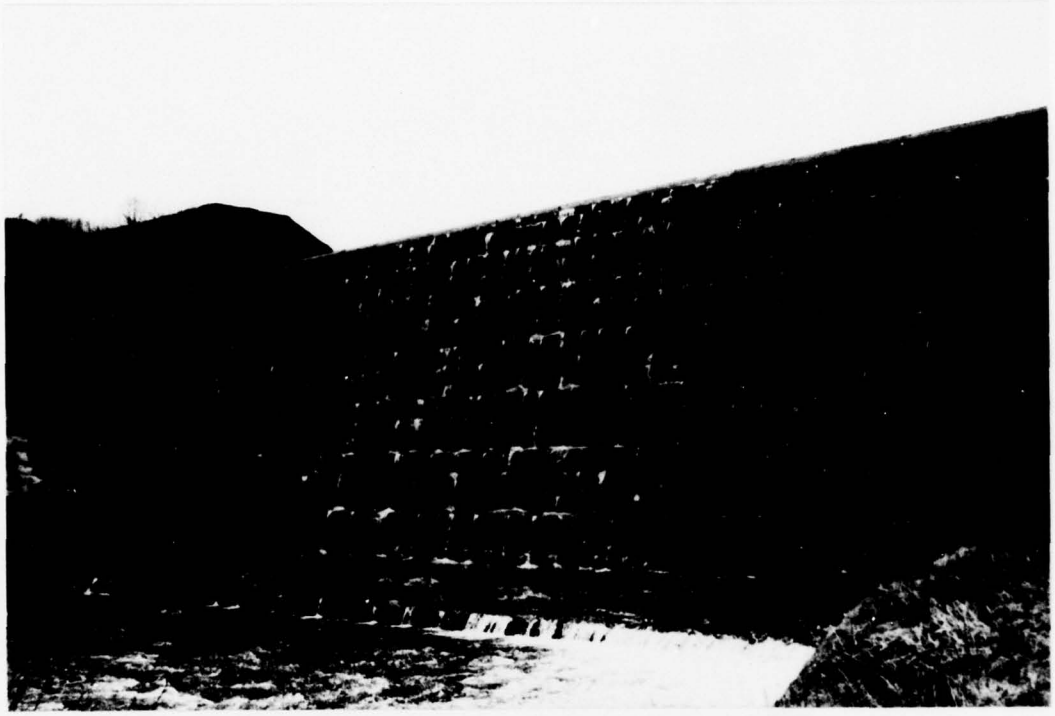
APPENDIX B

DOWNSTREAM SLOPE AND GATEHOUSE
(CARMEL MAIN DAM)

LEFT EMBANKMENT PORTION
(CARMEL MAIN DAM)

VIEW OF EMBANKMENT, SPILLWAY AND GATEHOUSE
FROM THE UPSTREAM DIRECTION
(CARMEL MAIN DAM)

DISCHARGE CONDUIT AND TAILRACE CHANNEL
(CARMEL MAIN DAM)



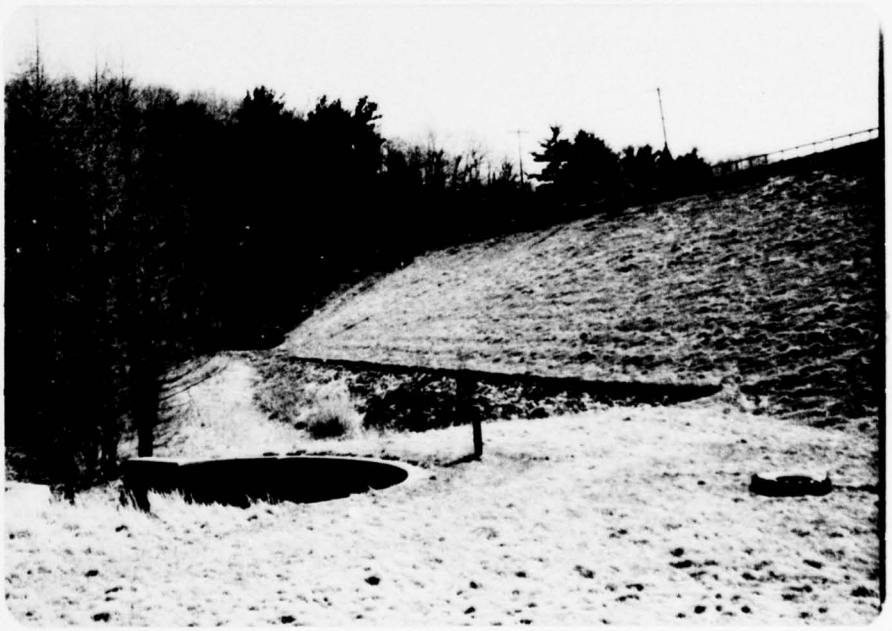
DOWNSTREAM SLOPE OF SPILLWAY SHOWING
SEEPAGE FLOW [OBSERVATION (L)]
(CARMEL MAIN DAM)

UPSTREAM SLOPE PROTECTION. SOME VEGETATION
GROWTH IS SHOWN. [OBSERVATION (A)]
(CARMEL MAIN DAM)

DAMAGE TO UPSTREAM SLOPE PROTECTION
LEFT OF SPILLWAY WALL [OBSERVATION (G)]
(CARMEL MAIN DAM)

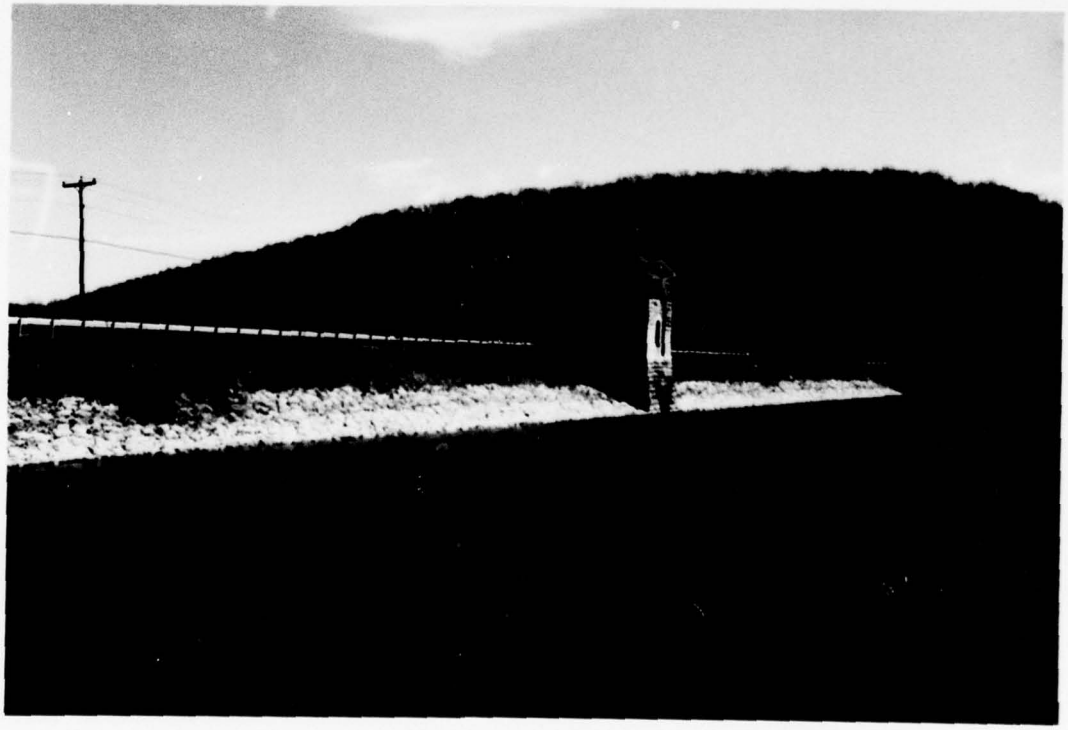
SEEPAGE FLOW AT ABUTMENT CONTACT
OF LEFT EMBANKMENT [OBSERVATION (B)]
(CARMEL MAIN DAM)

SPILLWAY CREST, DISLOCATED STONES OF THE UPPER TWO COURSES AND SEEPAGE FLOW ARE SHOWN [OBSERVATIONS (M) AND (L)]
(CARMEL MAIN DAM)



GENERAL VIEW OF AUXILIARY DAM AND OUTLET FOUNTAIN

VIEW OF EMBANKMENT AND GATEHOUSE FOR THE UPSTREAM DIRECTION
(AUXILIARY DAM)



VIEW OF EMBANKMENT, GATEHOUSE AND SHAFT 10
FROM THE UPSTREAM DIRECTION
(AUXILIARY DAM)

SURFACE EROSION AT LEFT ABUTMENT CONTACT [OBSERVATION (I)] (AUXILIARY DAM)

DISCHARGE POINT OF FOUNDATION DRAINAGE SYSTEM. Shows Debris & Partial Clogging (Observation(H)] (AUXILIARY DAM)

ENGINEERING DATA CHECKLIST

APPENDIX C

CHECKLIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

NAME OF DAM Hair Carmel and Auxiliary Dam

ID # 29

ITEM	REMARKS
AS-BUILT DRAWINGS	see Drawing list.
REGIONAL VICINITY MAP	USGS maps: Lake Carmel, Oscawana Lake, Poughquag and Hopewell Junction quadrangles - 7.5 minute series 1:24000
CONSTRUCTION HISTORY	Some information together with construction photographs is included in the Aqueduct Commission Report 1887-95.
TYPICAL SECTIONS OF DAM	Shown on the available drawings.
OUTLETS-PLAN	— " —
-DETAILS	some sketches
-CONSTRAINTS	
-DISCHARGE RATINGS	3 pages out of 6 of the spillway rating has been found.
RAINFALL/RESERVOIR RECORDS	Daily record is available in the Reference Distort Office of BOWS

ITEM	REMARKS
DESIGN REPORTS	None
GEOLOGY REPORTS	None. except on regional geology
DESIGN COMPUTATIONS	None
HYDROLOGY & HYDRAULICS	
DAM STABILITY	None
SEEPAGE STUDIES	Some data in USBR Tech Memo 337 (1934)
MATERIALS INVESTIGATIONS	No data
BORING RECORDS	"
LABORATORY	"
FIELD	"
POST-CONSTRUCTION SURVEYS OF DAM	No data
BORROW SOURCES	"

ITEM	REMARKS
MONITORING SYSTEMS	3 piezometers in the main dam and 3 in auxiliary dam. They had been placed in the early 1920-s. The piezometers are not in use.
MODIFICATIONS	The top two rows of stones at the spillway crest have been replaced
HIGH POOL RECORDS	Available in the National Office of Bows
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	Seepage studies described in USBR. T.M 389 and in ASCE Trans Vol 87
PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION	None Recorded
REPORTS	
MAINTENANCE OPERATION RECORDS	Record kept in the Season Office of Bows in Carmel.

ITEM	REMARKS
SPILLWAY PLAN	shown on available drawings
SECTIONS	"
DETAILS	No details
OPERATING EQUIPMENT PLANS & DETAILS	Some data shown on the available drawings

VISUAL INSPECTION CHECKLIST

APPENDIX D

VISUAL INSPECTION CHECKLIST

1. Basic Data

a. General Main Carmel and

Name of Dam Ancilian Dam Hazard Category _____

County Putnam ID# 29

Stream Name West Branch Croton Tributary of Croton

Location Putnam County Nearest Town (P.O.) Carmel

Main — Longitude 41° 24 25" Latitude 73° 41' 25"
Ancilian — Longitude 41° 23' 59" Latitude 73° 42' 22" Other Directions _____

On Rt 6 between Carmel and Mahopac

Date of Insp Apr 24 78 Weather Sunny Temperature 55 - 70°

b. Inspection Personnel [illegible] ISAACS

Harold Lerenthal

Mike Grant

c. Persons Contacted Tom Burrell Jackson Engr

Ed Spirra Foreman

d. History: Date Constructed 1895

Present Owner City of New York

Designed by Aqueduct Commissioners of NY

Constructed by M S Coleman

Recent History _____

2. Technical Data

Type of Dam Earth fill with concrete core Drainage Area 42.87 SQ Mi ~~Acres~~

Height Main 50 ft Ancil 50 ft Length Main 1794.5 ft Ancil 741 ft

Upstream Slope 1 on 2 both Downstream Slope Main 1 on 2.5 Ancil 1 on 2.0

Crest Width 25 ft. Freeboard ~~at~~ over Spillway Crest 12 ft

Low Level Control: (Type and Size) Also at Sheet 10 four 6 ft by 12 ft sluice gates discharge into Delaware Canal. Near: two 24 by 60 in sluice gates Ark: One 24 by 60 in sluice gate

Valve Condition _____

~~Emergency~~ Spillway Type (Material) Masonry rubble stone faced Width 260 ft

Side Slopes As shown on drawings.

Height (Crest to Top) _____

Exit Slope _____

Exit Length _____

Ponded Surface Area _____ Acres

Capacity (Normal Level) _____ Acre Feet

Capacity Emergency Spillway Level ____ Acre Feet

3. Embankment Flashboards here been removed after 1955 flood.

a. Crest _____

(1) Vertical Alignment No evidence of deformation

(2) Horizontal Alignment — " —

(3) Longitudinal Surface Cracks None evident

(4) Transverse Surface Cracks — " —

(5) General Condition of Surface Concrete walls appear generally good & maintained.

(6) Miscellaneous _____

b. Upstream Slope Over 10 ft grass covered
below this covered by hand placed stone
& slope protection

(1) Undesirable Growth or Debris
Some at a few locations

(2) Sloughing, Subsidence, or Depressions
Depressions in the riprap on both dams
adjacent to spillway walls

(3) Slope Protection Hand placed stone in
excellent condition except in noted
areas.

(a) Condition of Riprap — " —

(b) Durability of Individual Stones Highly durable -
mostly igneous rock

(c) Adequacy of Slope Protection Against Waves and Runoff
Adequate

(d) Gradation of Slope Protection - Localized Areas of Fine Material
Smaller stones only occasionally -
one such area main dam at right
abutment.

(4) Surface Cracks One crack noted between
in main abutment slope protection
right of spillway wall

c. Downstream Slope

(1) Undesirable Growth or Debris
Well maintained grass - some small
bushes right of spillway on main
dam

(2) Sloughing, Subsidence, or Depressions; Abnormal Bulges or Non-Uniformity

Some irregularities near toe of main dam where the material is wet - on both right and left sides.

(3) Surface Cracks on Face of Slope None evident

(4) Surface Cracks or Evidence of Heaving at Embankment Toe

None except the minor irregularities mentioned in (2)

(5) Wet of Saturated Areas or Other Evidence of Seepage on Face of Slope; Evidence of "Piping" or "Boils"

Wet areas at the lower abutment portions of main dam - right and left side. Water seepage on the left side.

(6) Fill Contact with Outlet Structure

No problems evident

(7) Condition of Grass Slope Protection

generally well maintained

d. Abutments

(1) Erosion of Contact of Embankment with Abutment from Surface Water Runoff, Upstream or Downstream

Minor erosion at left side, downstream slope of auxiliary dam.

(2) Springs or Indications of Seepage Along Contact of Embankment with the Abutments

Spring and seepage at left abutment main dam. Spring enclosed in a brick vault at right abutment auxiliary dam. This vault is part of the foundation drainage system at auxiliary dam.

(3) Springs or Indications of Seepage in Areas a Short Distance Downstream of Embankment - Abutment Tie-in

Some wet areas at both dams - no springs or seepage. Water is flowing out from the foundation drainage system of auxiliary dam

e. Area Downstream of Embankment, Including Tailrace Channel

Well established stream bed at main dam, heavy vegetative growth downstream of aux dam.

(1) Localized Subsidence, Depressions, Sinkholes, Etc.

None

(2) Evidence of "Piping" or "Boils"

None

(3) Unusual Presence of Lush Growth, such as Swamp Grass, etc.

No unusual vegetation

(4) Unusual Muddy Water in Downstream Channel

No

(5) Sloughing or Erosion

No major erosion

(6) Surface Cracks or Evidence of Heaving Beyond Embankment, Toe

None

(7) Stability of Tailrace Channel Sideslopes

No major erosion or stability problem is noted.

(8) Condition of Tailrace Channel Riprap

No riprap

(9) Adequacy of Slope Protection Against Waves, Currents and Surface Runoff

Adequate for normal discharges.

(10) Miscellaneous Some debris in the stream downstream of aux dam

f. Drainage System Auxiliary dam has a foundation drain system which appears to be in good condition and functioning.

(1) Condition of Relief Wells, Drains and Appurtenances

The drain system requires cleaning and removal of sand deposit.

(2) Unusual Increase or Decrease in Discharge from Relief Wells

No relief wells

4. Instrumentation

(1) Monumentation/Surveys

No periodic survey

(2) Observation Wells None

(3) Weirs None

The auxiliary dam drainage system had measuring weirs but these are not in operational condition now.

(4) Piezometers 3 on main dam and 3 on east dam. These standpipe piezometers have been placed in 1920-S. The piezometers are not in use.

(Other)

5. Reservoir

a. Slopes No sign of instability

b. Sedimentation No indication of excessive sedimentation.

6. Spillways

a. Principal Spillway: Inlet Condition } see Section 1.2.j for data
Pipe Condition } pertaining to "Regulating Outlets".

General Remarks (include information such as recently repaired, potential for debris accumulation, special items of note, etc.)

After 1950 water was no longer discharged over the spillway because the conduit system was enlarged and became possible to repair and replace the top masonry courses which were probably in bad shape after 55 years of service.

b. Emergency Spillway: General Condition The stepped downstream surface of the spillway appeared in satisfactory condition despite pronounced downstream curvature of the top masonry courses near its middle and some leakage from the joints of these top courses, with water flowing down the stepped surface it was difficult to determine whether there was any additional leakage from the joints of the lower courses. ~~Erosion~~ Holes for flashboards were visible but are no longer used. 1¼" ϕ steel rods are also visible on the top stones at irregular intervals. They are probably used as anchors tying the new masonry course to those below. No drawings or details of rods are available.

~~Tree Growth~~ ~~Other Observations~~

7. Structural (if required) See Attached Appendix

Stability calculations are not required for Phase I Dam Inspection

8. Downstream Channel

a. Condition (obstructions, debris, etc.) The downstream channel of main dam is masonry, lined and appears in good condition. There was no accumulation of debris in the channel. Water was being discharged into channel to supply the local water requirements.

b. Slopes

c. Approximate No. Homes and Population

d. General

Kalman Szalay
TEAM CAPTAIN

STRUCTURAL INSPECTION CHECKLIST

PHASE I DAM INSPECTION

Dam Type - earth fill with center masonry core. There are

1. Concrete Surfaces no exposed concrete surfaces. The spillway walls and downstream face are lined with masonry blocks. The stream bed below the spillway is amply protected by heavy paving. The masonry facing appears in good condition

2. Structural Cracking No structural cracking is visible.

3. Movement - Horizontal and Vertical Alignment There is no apparent change in either the horizontal or vertical alignment of the spillway except for the top masonry courses which have curved slightly downstream because of ice pressure.

4. Junctions with Abutments or Embankments There is a Gate House with upstream and downstream regulation at the junction of the Spillway and the main embankment.

5. Drains - Foundation, Joint, Face No drains under the spillway structure are visible or indicated on the drawings.

6. Water Passages, Conduits, Sluices In addition to the water leaking through the joints of the uppermost masonry courses water is discharged from the Gate House into the channel which feeds the West Branch of the Croton River

7. Seepage or Leakage There is some leakage from the joints of the top masonry courses especially near the middle of the spillway

8. Monolith Joints - Construction Joints there are no concrete structures - no monolith joints or construction joints.

9. Foundation No apparent problem. Stone facing at downstream base of spillway is sound and shows no sign of movement or cracking.

10. Abutments there are no structural (concrete) abutments.

11. Control Gates There are no structural control gates on the spillway. There is a gate house on the left side of the spillway, which has both upstream and downstream regulation (see 1.3 1j)

12. Approach and Outlet Channels Water leaking thru the spillway falls on heavy stone steps contained between curved wingwalls. The streambed directly downstream is protected by heavy paving.

13. Stilling Basin – There is no stilling basin.

14. Intake Structure There is no intake structure. The gate house has upstream regulation (two 24"x60" manually operated sluice gates.

15. Settlement No apparent or significant settlement of the spillway structure.

16. Stability
    a. Overturning — No stability computations are available for the spillway structure.
    b. Sliding — No stability computations are required for PHASE I
    c. Seismic — After 80 years of operation – none seem necessary

17. Instrumentation
    a. Alignment — None installed
    b. Uplift
    c. Seismic

18. Miscellaneous Check lower portion of downstream spillway face for leaks at masonry joints when reservoir level is much below the crest.

Existing leakage should be observed regularly to see whether flow is increasing.

HYDROLOGIC DATA AND COMPUTATIONS

APPENDIX E

Job No. 1427 — TIPPETTS-ABBETT-McCARTHY-STRATTON — ENGINEERS AND ARCHITECTS — NEW YORK — Sheet ___ of ___

Project Dam Investigation — Date 5/31/57

Subject Clay Chapel Dam — By GKT

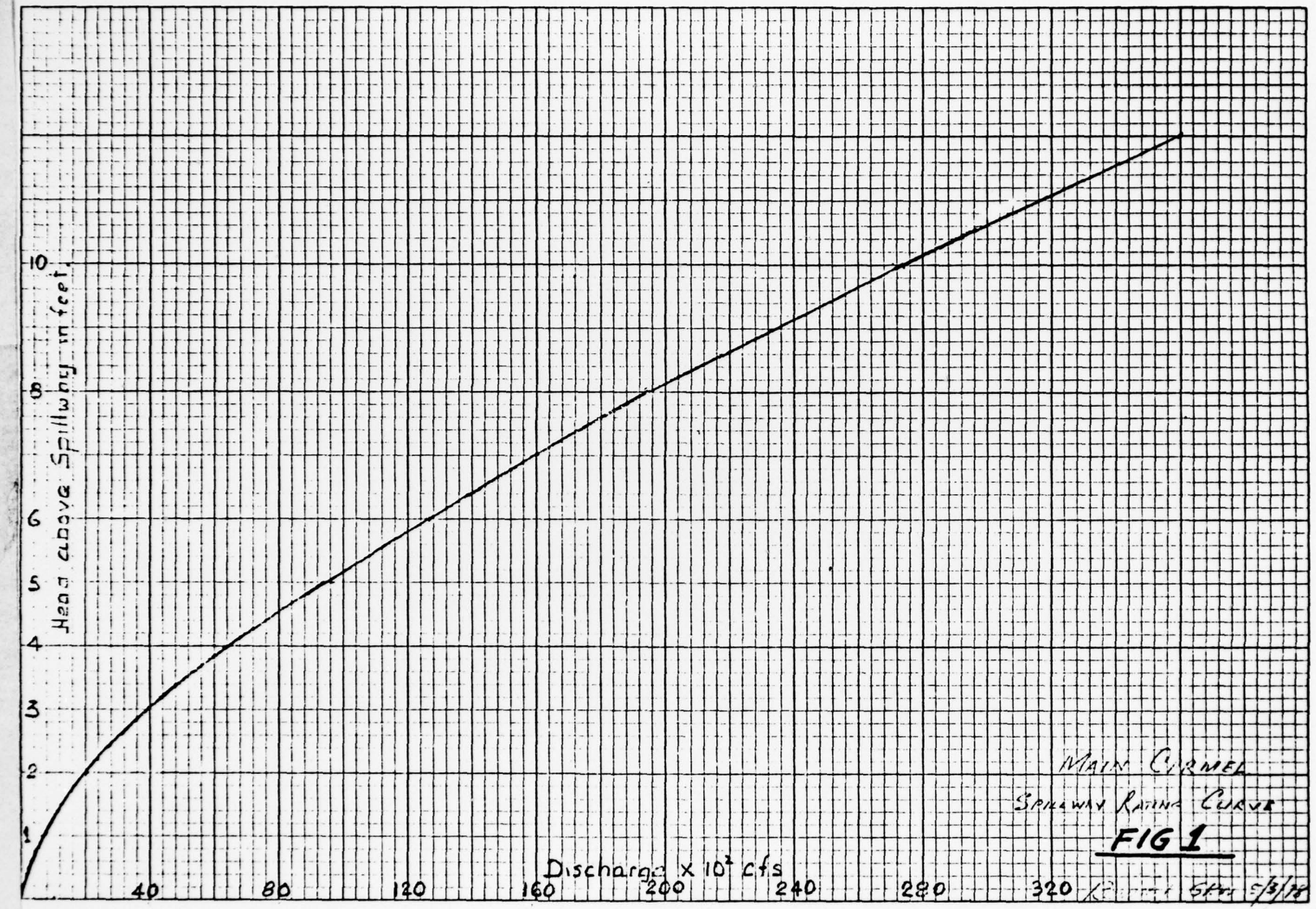
Tailwater Rating Curve — Ch'k. by ___

Spillway Rating — Length = 260'

Head	C	Q (cfs)	
0.5	2.62	241	} Data for Board of
1.00	2.63	685	
1.50	2.65	1260	} Water Supply
2.00	2.72	2000	
3.00	2.92	3745	} C from King's Handbook
4.00	3.07	6386	
5.00	3.32	9651	
6.00	3.33	12724	
7.00	3.33	16055	
8.00	3.33	19591	
10.00	3.33	27379	
12.00	3.33	35490	

Flood of Record

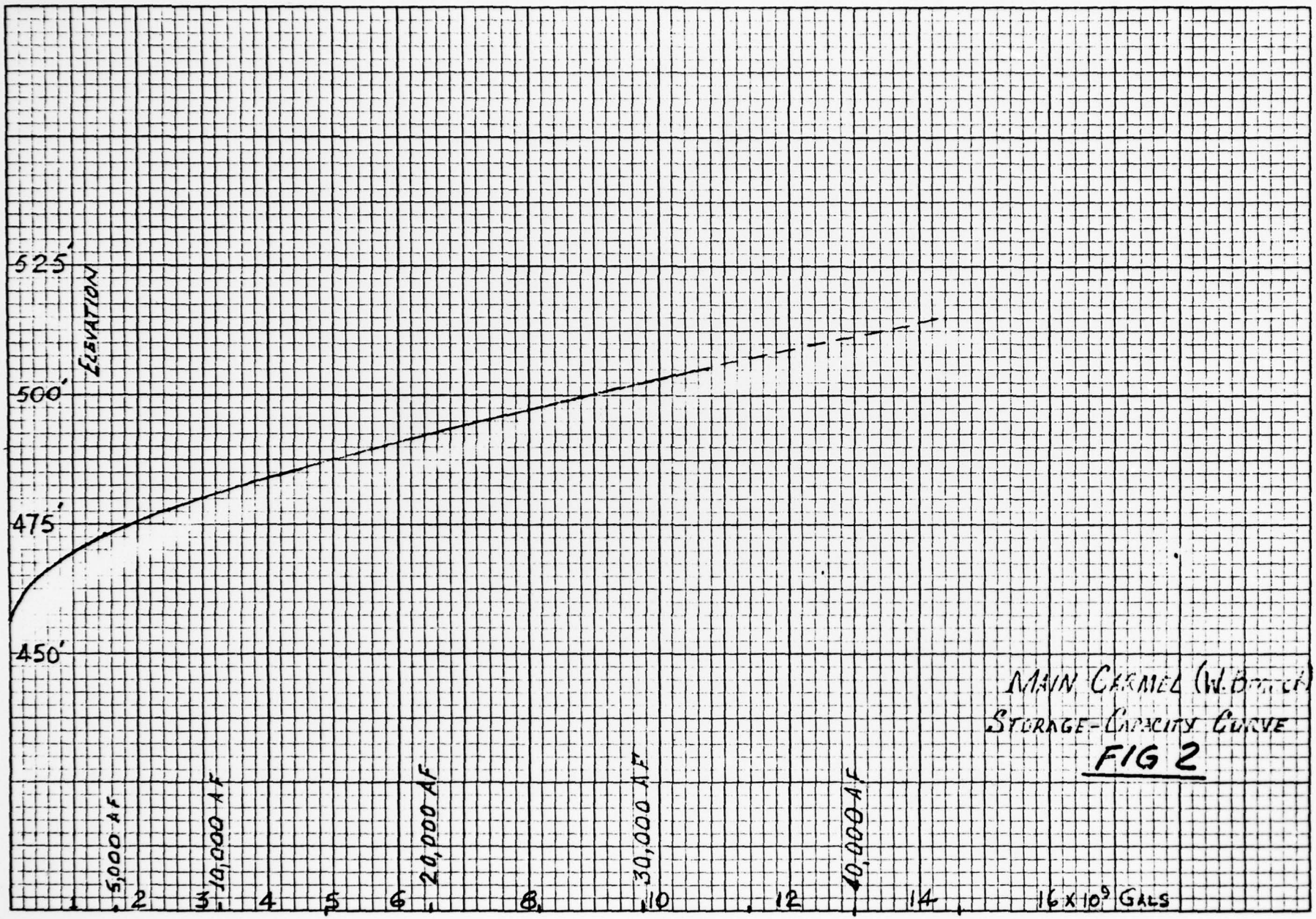
Date	Elev.	Head	Q	
Aug. 2, 1955		1.85	1900	← Discharge down 10' at beginning of flood
Oct. 16 1955		2.83	3577	



MAIN CARMEL
SPILLWAY RATING CURVE

FIG 1

Sht 5/3/38



MAIN CARMEL (W. BRANCH)
STORAGE-CAPACITY CURVE
FIG 2

LIST OF REFERENCES

APPENDIX F

APPENDIX F

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